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RAYMOND C. MOORE
Editor

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THE CRETACEOUS OF WEST TEXAS AND ITS OIL POSSIBILITIES

By Charles Laurence Baker

INTRODUCTION

The very estimable gentleman who has drafted the writer for the present paper has committed two errors. First, he has assigned a subject to one whose ignorance of the matter is not less than colossal, and, in so doing has violated every well-recognized principle of the *selective* draft. He must have followed the precedent set by a certain European geologist who said of himself that whenever he encountered a subject of which he knew nothing he at once proceeded to write a book about it! We may at least be allowed our own metal reservations concerning the wisdom of such a policy in these days of affliction when far too many people are producing surplus of books and articles upon matters about which they know nothing.

The second error is in having neglected to state just what territory should be included in "West Texas." Perhaps this is well, for West Texas is about as difficult to define as is the American West. The writer will proceed to take every advantage by adopting the precedent of our friends from New England who persist in including in the West every place beyond the Susquehanna. Thus we claim for West Texas all that territory beyond Brazos river. If pressed for defense we will say that the Brazos is the most valid line of demarcation between the East and West Texas Coastal Plain. And inasmuch as Texas, again following precedent, has never been willing to accept the Rio Grande as her southwesternmost limit we may include a large part of northeastern Mexico. For venturing as far as the Rocky mountains we have no justification other than that of geology, which counter to the principles of the Congress of Versailles, recognizes no frontiers, "scientific" or otherwise.

It is impossible to prevent any active mind from generalizing and, indeed, the capacity for generalization is one of the highest human attributes. Still, there are far too many generalizations accepted with the

assurance of dogma. The route of progress is everywhere strewn with the wrecks of countless abandoned theories and hypotheses and its present and future course is beset with many like obstacles. The pioneer geologist is especially doomed to misfortune; and it is well for us to recognize that west of the Mississippi at least we are all still pioneer geologists. Most pioneer generalizations will be found to have been based mainly on facts far too few in number. A preconceived notion, the dictum of some authority accepted without the critical examination which experience and accurate knowledge always should, but far too seldom does involve, is one of the most dangerous enemies that any science and scientist must strive to avoid. There are extremely few men critical enough of either their own or other's results. The rule of Nature is a diversity almost infinite but most of us are so constituted that apparent simplicity is the thing that makes most appeal.

The immense extent and diversity of the Cretaceous in Texas makes the task of knowing it thoroughly an impossibility for any one man. Before our conclusions and interpretations deserve any great weight we need to accumulate a very large mass of facts. These facts, once procured, will need the varied judgments of a number of minds.

AGE RELATIONSHIPS OF THE TEXAS CRETACEOUS

Some may hold that problems of correlation and nomenclature are of secondary importance to the petroleum geologist. Nevertheless, any misconception or outright error here or anywhere else may lead to serious consequences. Our first task here is to seek to know what the Texas Cretaceous is likely to prove to be when compared with the Cretaceous elsewhere. Now, for precisely the same reasons that the American Paleozoic succession from Lower Cambrian to the top of the Mississippian is likely always to be the standard for the whole earth, Europe affords the standard section for the Cretaceous. The European Cretaceous is the most complete yet known, it has been the most thoroughly studied, and its subdivisions have priority. The pioneer work in Mexico of Emil Böse and Carl Burckhardt present a number of carefully studied type sections of Cretaceous, closely correlated, largely by aid of their ammonite faunas, with the European strata. It is now possible to correlate in a general way the Texas Cretaceous with the Mexican and so to learn much of the comparisons between Texas and Europe.

The major subdivisions of the European Cretaceous are from the base to the top the Neocomian, Aptian, Albian, Cenoman-

ian, Turonian and Senonian. The Europeans, generally make two major divisions, the Lower comprising the first three, and the Upper, composed of the remaining three. If a threefold division is made the Neocomian and Aptian are regarded as Lower, the Albian and Cenomanian as Middle, and the Turonian and Senonian as Upper.

The only Neocomian known in Texas is in the Malone Mountains. The fossils known from the Malone Mountains are lower Neocomian but as Aptian strata are also known here the upper Neocomian may also be present. In West Texas the Travis Peak and Glen Rose probably represent the Aptian. The Travis Peak is certainly Aptian. Somewhat less certain is the position of the Fredericksburg division, the lower part of which seems certainly Albian and the upper part possibly lower Cenomanian. All of the Washita division is thought to be Cenomanian but the Buda, although upper Cenomanian, may not be uppermost Cenomanian. Berry thinks the plant fossils of the Woodbine and Dakota are also Cenomanian. The Eagle Ford is Turonian, the Austin Chalk, Taylor and probably all of the typical Navarro are Senonian and the uppermost strata of the Eagle Pass series probably belong to the highest marine Cretaceous known in the world, the Maestrichian of Holland and Belgium.

There is nothing yet known that either proves or disproves absolutely Berry's assignment of the Dakota and Woodbine to the upper Cenomanian. The Eagle Ford has not yet given fossils which would indicate whether it represents all of the Turonian or only the upper portions of that division. The important point is whether the Eagle Ford includes lowermost Turonian. The characteristic fossil of the Eagle Ford, *Inoceramus labiatus*, is most common in the lower Turonian of Europe but occurs also in the upper. It is highly probable that the Woodbine-Dakota, since it is a greatly transgressing formation, contains higher strata at its base successively farther in the directions of its margins than the lowermost beds of its Texas outcrops. If future work should show that the Woodbine belongs in the Cenomanian it would be most probable, though not entirely certain that the Woodbine and

Buda are contemporaneous formations. Pertinent facts are that (1) no satisfactory evidence has yet been found of any physical break at the base of the Woodbine, (2) that no satisfactory explanation has ever been advanced for the disappearance of the Woodbine west of the Brazos, granting that it is younger than the Buda, (3) that the direct superposition of the Eagle Ford shales upon the Buda in West Texas has a suspicious appearance of being a normal and continuous succession, and that (4) the Cretaceous succession in northeast Texas, Louisiana and Arkansas is primarily one of terrigenous sediments while the contemporaneous beds west of the Brazos were in the main deposited in clearer waters.

If we consider Comanchean as synonymous with Lower Cretaceous we find that the Texas Lower Cretaceous includes less in its base and more in its top than the standard section of Europe and Mexico. However, should the Woodbine prove to be lower Turonian the Texas Comanchean Trinity to Washita inclusive would include both the upper half of the Lower and the Middle Cretaceous of European authorities, who use the three-fold subdivision. Should the Woodbine be upper Cenomanian we have been drawing a division line in Texas entirely at variance with established usage in any other part of the world.

PROPOSAL TO ELIMINATE THE COMANCHEAN PERIOD

The attempt has been made by some authorities to elevate the Comanchean of Texas to the dignity of a geological system. The adherents of this assert that the succession of strata so rendered represents a complete depositional cycle, beginning with a widespread marine submergence and ending with an equally widespread emergence of the sea. Whether this is really true in Texas we shall discuss farther on. It is certainly not true in adjacent Mexico, it is probably in no way true in California, and is certainly not true in Europe or in any other known region. In fact, the burden of proof rests emphatically upon those who hold that any geologic period, viewed in its worldwide manifestations and, indeed, even in its extent over a single continental expanse, represents a complete cycle of deposition or is marked off by anything approaching a universality of diastrophic periodicity. Furthermore, we now can

know enough of the world to venture to state with a good deal of probability that diastrophism has never been quiescent on the planet, that it is not catastrophic but probably as normal as any other major phenomenon, that on the earth as a whole there may have been continuous diastrophism, and that it mostly depends in what particular region the original study, delimitation and subdivision of a period was made as to what has come to be included within that period. If the geologic time scale had first been made in America instead of in Europe we would have different systems than we now have and it is entirely possible to construct a time scale for the Pacific Coast quite different from that used in the eastern half of the continent, both of them based on the same considerations and the one quite as reasonable as the other.

When we come to test the depositional cycle view on the basis of which it is asserted that the Texas Comanchean is a typical geoloic system we find that it is founded on the supposed but as yet unproved erosional and faunal unconformity at the base of the Woodbine, on the supposed widespread marine transgression of the Dakota-Woodbine and on the widespread transgression beginning with the Trinity. But we find widespread transgressions occuring *within* geologic periods. The Lower Cretaceous succeeds the Jurassic in central and southern Mexico in as perfect conformity as can be found anywhere. If the sea retreated after Buda deposition and advanced again at the beginning of Eagle Ford time why have we not found in the numerous contact exposures of West Texas the slightest evidence of an erosion surface or of a basal conglomerate? It is not necsessary, be it admitted, to find either of these to demonstrate a time break but as yet this time break has not been shown. In reality the Comanchean sea was transgressing farther and farther over the land of West Texas until near the close of the Washita. A depositional cycle ending in the midst of a marine transgression is only half complete. Perhaps this same transgression was merely continued in the Upper Cretaceous.

If we take the entire extent of all Cretaceous time and confine our area to the central third of the United States and

Canada included between the Mexican Gulf and the Arctic Ocean we have a much more typical cycle of deposition, beginning with the Trinity, reaching its greatest extent in Benton or Niobrara and withdrawing from the continent near the beginning of the Laramie. But when we come to Mexico we find that the beginning of this cycle was at the base of the upper Jurassic in the state of San Luis Potosi and perhaps even in the upper Triassic in the states of Vera Cruz and Zacatecas. In our search for theorotical periods it will assuredly not do to take in too much territory.

The eminently practical thing to do is to forget as soon as possible that there has ever been such an idea as the Comanchean period. At the same time let us accept the European Cretaceous classification so that ourselves as well as the rest of the world will know what we mean when we say Cretaceous. Also it might be well to cease using the terms Eagle Ford, Austin Chalk and Taylor and go back to the good old terms Benton, Niobrara and Pierre. The older terms have priority and they mean the same things as our parochial Texas names. And if American geology is burdened with any one incubus greater than another it is with a multiplicity of local formation names. There is no royal road to geologic correlation, either by diastrophism or lithologic resemblances. We can get reasonably certain results only with fossils and secondarily, in a few cases, with some unusual lithologic peculiarities. In making use of the latter we should be mindful that diversity is the normal expectation and that uniformity over large areas is about the most difficult thing of all to explain.

PHYSICAL HISTORY OF TEXAS CRETACEOUS AS APPLIED TO ORIGIN

Structural conditions favorable for the storage of profitable amounts of bitumen are fairly well understood. But the most favorable structure conceivable will not yield oil unless oil is already there. Whenever the question arises of the advisability of prospecting untested regions, many miles from the outcrop of strata suspected of being bituminous and far from any known production, it becomes necessary to attempt to foretell, with as much of precision as may be possible, the conditions under which the suspected strata were deposited.

In order to do this it is necessary to possess knowledge of the stratigraphy over extensive areas and to know much of sedimentary processes both favorable and unfavorable for the accumulation of bituminous substances. This branch of the science of petroleum geology is still in its infancy and its future progress depends upon extensive knowledge of many different things. Petroleum geology is an applied science and as such can only progress in proportion to the amount of science there is to apply. The time is now come when we are called upon to advise concerning the undertaking of expensive explorations in places where there is little, direct, visible evidence of oil and gas and none of us are yet as fully prepared as we should be to undertake this service. Hence we must all be research men whether we will it or not. There is a vast difference between the broad-minded and widely-experienced geologist and the mere structure-hunter. The man who emerges ahead in the competitive struggle will prove to be the one who suffers no detail to escape him and who in his final conclusions has taken full cognizance of every line of evidence possibly available. All this necessitates much time and labor. Snap judgments and the taking of unjustifiable chances may be tolerated for the brief time while the present mania for petroleum is in full swing and while fortunate financiers seek to dispose of large excess profits but in the long run the successful economic geologist must be a scientist and as nearly as possible everything which that word means. Incidentally it may be remarked as a matter of personal opinion, that mere structure-hunting is about as interesting as the keeping of books in a village grocery store.

Paleogeography in its fullest sense constitutes one of the most prominent lines of investigation. The nature, extent, position and relief of land surfaces furnishing sediments, the climate conditions, the sites of marine currents, the constitution of the sediment and the content of the fossils are among the most promising subjects of inquiry. These necessarily demand the accumulation of data from large areas. As yet, there would appear to have been far too little accomplished in the investigation of the ecology of plant and animal life in the

shallow waters of oceans and seas, bays, deltas and estuaries. A probability often lost sight of, also, is that in the past certain animal and plant types may have occupied different environments than those in which they live today. Adaptation is one of the greatest conceivable processes by which evolution works. Unsuitability for further adaptation is likely one of the most potent causes for extinction of species, even whole classes and orders of organisms. Nature appears to have countless times repeated the same experiment, the success or failure of which has often depended and still depends upon something like a fortuituous combination of circumstances largely beyond the control of the organism itself. The possibility for combination and complexity of factors influencing a given organism, favorably or unfavorably, is infinite; the possibility of favorable adaptation by the organism necessarily restricted.

Plants as well as animals yield bitumen, for one of the world's greatest oil-bearing formations, the Monterey of California, is mostly built up of diatoms and the oil shales of northwestern Nevada almost certainly derive most of their bituminous content from vegetation, a part of which was apparently weedy plants which grew on dry land surfaces. In the present state of our knowledge it is not safe to assume that any species of plant or animal at some time or place may not have yielded bitumen.

For an organism to yield bitumen is one thing; for the bitumen to have been saved or made available for production are quite other things. Next in importance is the prevention of complete decay of the organic matter. This must be accomplished by rapid burial, generally under water. Burial under water alone merely inhibits decay and does not entirely prevent it. In order to prevent ultimate total decay it is necessary that the organic matter must either be buried under an impervious cover of sediment or else be absorbed by the sediment in such a way that further decomposition is indefinitely halted. Possibly in most cases both of these are necessary in order to entrap the dead organic matter. The sediment which mainly fulfills these conditions is argillaceous in composition with the texture of silt or fine clay. The relative amount of bituminous

material entrapped depends upon the proportion of sediment to organic material. If there is too much of the former there may be too little of the latter and if there is greater supply of organic matter than can be entrapped by the sediment there will be wastage of organic matter. In any event it is most probable that the bulk of the organic matter is wasted, hence the profitable supply of bituminous substance is the exception rather than the rule. Most of what is saved is later concentrated in favorable structures.

The bituminous matter has three possible known sources: some of it is contributed by organisms living on the site of its deposition; some of it may be brought by currents to its place of final rest; some may have come from adjoining land, either from a fresh water or dry land habitat.

The final reservoir rocks may be quite different from those in which the bitumen was deposited. They may either rest above or below the sites of deposition or may be at some distance horizontally from these sites.

We will not attempt to apply such general principles as these to all possibilities in the West Texas Cretaceous. What follows sets forth the writer's personal opinions. The paper is written in a foreign field, without access to the literature, and the facts are taken largely from memory.[1] The data on Mexico has ben very kindly furnished in part by Dr. Emil Böse, who has furnished also most of the facts for the correlation of the Texan with the European and Mexican Cretaceous, and is partly taken from unpublished field studies of Dr. Böse and the writer.

BEGINNING OF THE CRETACEOUS IN TEXAS

Aside from that portion now covered by the Cenozoic of the Gulf Coastal Plain concerning which we know nothing, Texas was, at the beginning of the Cretaceous, a land of very low relief, the Wichita Paleoplain of Hill. The only known region then submerged was in the vicinity of the Malone Mountains. This region had been submerged since the Upper Jurassic and

[1]For further lithologic and stratigraphic details reference is made to Bose's summary of the Cretaceous in a Review of the Geology of Texas.

perhaps longer. Nowhere else in Texas are Jurassic deposits known and probably most of the land was subject to erosion during the entire Jurassic. he latest previous marine sedimentation known was the Lower Permian. Since Lower Permian there had been some gentle folding in the Glass Mountains and in the formation of the Llano Estacado geosyncline. Much of the Upper Triassic river deposits had been eroded during the Jurassic and the gravels and sand from these and older rocks, was spread over low-lying land surfaces, much as was the later Lafayette, contributing to form a large part of the basal sediments of the advancing Trinity sea. The process of base-levelling had gone farther on the comparatively unresistant rocks of the later Paleozoic; monadnocks of more resistant earlier rocks probably persisted in the Marathon Mountains, the Ouachita, Massern and Arbuckle ranges, and possibly in the Wichita Mountains and Central Mineral Region. Possibly the Ouachita Mountains furnished considerable sediment to the Cretaceous sea; the others appear to have furnished comparatively little. At the opening of the period part of north-central Mexico and the Malone Mountains of Texas were under the sea. Parts of the Mexican states of Coahuila and Nuevo Leon were land areas.

THE TRINITY

The Trinity submergence began at the south. The Upper Jurassic marine limestones of the Nuevo Leon-Coahuila boundary between Monterrey and Saltillo, Mexico, are overlain by something like three thousand feet of sandstones and conglomerates. There appears to be here a time break between Jurassic and Cretaceous. In southwestern Coahuila (Sierra del Sobaco), north of San Pedro de las Colonias, Böse found Lower Permian marine sediments strongly tilted, intruded by pre-Cretaceous syenite and overlain with angular unconformity by Cretaceous sediments carrying *Orbitulina texana*, a characteristic upper Trinity fossil. These are overlain by beds of gypsum which may possibly be the equivalent of gypsum in the Malone Mountains, Trans-Pecos Texas. In the western part of the Mississippi Embayment region (including northeastern Texas) the Trinity sea reached to the south-

ern flanks of the Ouachita, Massern and Arbuckle Mountains. The predominance of terrigenous sediments in the Cretaceous of the western Mississippi Embayment strongly suggests deltaic conditions in which were laid down maturely weathered land derived materials. The Lower Cretaceous of northeast Texas, Louisiana and southern Arkansas may yield profitable supplies of oil and gas.

There appear to have been no large rivers or at least no large supplies of sediment entering the Trinity sea of West Texas. Probably the terrigenous sediments of the basal Trinity were mostly found in place by the sea as it gradually encroached. At the end of the Trinity the sea had reached as far north in Trans-Pecos Texas as a line running from a point about southwest of the town of Marathon to the Quitman Mountains. The sea then covered part but perhaps not all of the Edwards Plateau and thence its strand line had a northerly or northeasterly direction to Red river. Along Red river it apparently extended at least as far west as Clay county.

The basal deposits of the Trinity division are younger farther and farther north. At the same time that upper Trinity terrigenous deposits were laid down in Texas beds of very pure limestone were deposited in the clear waters of northern Mexico. The time represented by the Glen Rose argillacous limestone to the south was occupied to the north by the deposition of gravels, sands and clays. Hence it is quite wrong to base a chronologic succession of the Texas Trinity on lithology alone. That there was relatively little sediment coming directly into the sea west of the Brazos is shown by the rapid transition offshore from terrigenous deposits to the predominant limestone of the Glen Rose. Possibly much of the argillaceous content of the Glen Rose may have been brought by currents from the Western Mississippi Embayment. The Glen Rose from Travis county westward to Mexico shows a remarkable, oft-repeated alternation of beds of purer limestone with more marly and argillaceous ones.

The basal beds of the Trinity probably contain little oil. The shallow water along the shore line probably was too dirty to permit abundant life. The shore remained a relatively short

time in one situation. Likely the sediments were too coarse to entrap much bituminous matter or relatively there was a much greater proportion of sediment than bituminous matter. The oil shows in the basal Trinity, found at various places from Red river in Montague county to the Rio Grande in Presidio county may have been derived from underlying formations or may be indigenous to the basal Trinity, which contains as much vegetal as animal remains. Altogether, there is probably little oil indigenous to the basal Trinity, although in some localities it is possible that seepage from underlying rocks may yield a profitable supply.

The Glen Rose must have been a fairly clear water formation. The terrigenous material it contains is very fine in texture. It is probable, judging from northern Mexican conditions, that the Glen Rose passes a short distance seaward from its present outcrop into a pure limestone. The Glen Rose is not, strictly speaking, a shoreline deposit, but its fossils are organisms of shallow water habitat. There is much organically-derived calcium carbonate, apparently deposited as comminuted shell fragments. These may in part have been deposited by undertow. Some of the shells likely underwent partial solution before deposition. The proportion of silt was not great enough to entrap much bituminous material. The deposits were not sufficiently impervious, since they had a large content of lime, to prevent further decay of the bituminous material. There is relatively little bitumen in Glen Rose strata and what there is is still largely absorbed by the argillaceous part.

The Glen Rose of the Trans-Pecos region consists of alternations of terrigenous strata and limestone. The formation becomes much more limey toward the Big Bend of the Rio Grande. The Glen Rose of the Burro Mountains of northern Coahuila has the same general characteristics of that of Edward county but south of the Burro Mountains the Glen Rose horizon is occupied by heavy pure limestones. In the Burro Mountains the Glen Rose may be at least 2,000 thick.

THE FREDERICKSBURG

The Walnut Clay horizon in the eastern part of West Texas much resembles the more argillaceous portions of the Glen

Rose. It is mostly—and especially to the westward—a calcareous marl and limestone rather than a clay. It is thin, probably not averaging over fifty feet in thickness. The writer has seen the horizon with its characteristic fossils on upper Nueces river and also as far west as the Burro Mountains of northern Coahuila. It contains many shallow water fossils, particularly of the Ostreidae *(Exogyra texana)* and Echinoidea. The depositional conditions of the Walnut were mainly the same as those of the Glen Rose.

The greatest thickness of the Fredericksburg in Texas is found in the Trans-Pecos region. The base of the Trans-Pecos Fredericksburg in the region of and north of the shore line of the Upper Trinity consists of littoral deposits of conglomerates, sandstone, shales, clays and argillaceous limestones. These shore line deposits are found in local facies and various thicknesses in the Quitman Mountains, Finlay Mountains, Shafter district, Cienega Mountains, Altuda Mountain, Glass Mountains and the southern flanks of the Delaware mountains. In the Finlay Glass and Delaware mountains Fredericksburg deposits directly overlie the Lower Permian, showing a continued transgression of the sea to the northward. In the Big Bend region was a sea of clear water and the entire Fredericksburg shows the heavy-bedded pure limestone facies so typical in northeastern Mexico.

The Comanche Peak and Edwards limestones are to be considered as a depositional unit although the Comanche Peak limestone east of San Antonio shows terrigenous material which increases in amount towards the Western Mississippi Embayment. The most striking characteristic of the Comanche Peak-Edwards is general uniformity in composition over a vast area in West Texas and northern Mexico. In Coke county, on the north side of the Edwards Plateau, the Edwards-Comanche Peak is separated by only a few feet of marly Cretaceous from the underlying Upper Triassic. West of San Antonio the amount of mechanically derived sediment may be said to be negligible. The chert and other silicious matter of the Edwards was probably derived from organisms. The fossils

show that some of it certainly was. Life was very abundant in that sea. The bottom must have sunk slowly to the west and to the south. The thinnest section of Edwards-Comanche Peak in West Texas occurs on the southern flank of the Delaware Mountains. This locality was near the Edwards shore line.

The conditions were not favorable for the preservation of bituminous matter during Fredericksburg time in Texas, notwithstanding that such a large proportion of its deposits are composed of the hard parts of organisms. It would be difficult to find a formation more barren of oil than the Edwards of West Texas and northern Mexico. We really know no heavy deposit of pure limestone anywhere which shows indubitable evidence of having been directly the source of any important amount of oil. The Edwards has plenty of porosity, most of which has come through secondary changes after deposition, but there are no important bituminous horizons either above or below it which could have contributed any noteworthy amount of oil.

THE WASHITA

There was a great northward advance of the sea during the Washita. The northern limits of this advance are yet unknown. Twenhofel, who has recently re-studied the Kansas sections, holds that all the Kansas Cretaceous older than the Benton belongs to the Cenomanian. This includes the Dakota of Kansas. The sea probably reached as far as Canon City, Colorado, and may have reached as far north as the Wind River Basin of central Wyoming. Some of the rocks directly underlying the Dakota in northeastern New Mexico may be Washita. The marls in the vicinity of Tucumcari, New Mexico and in Bailey county, Texas, carry a fossil (*Ostrea quadriplicata)* which has never been found in strata older than Georgetown. In the Cornudas Mountains, northern Trans-Pecos Texas, the Washita directly overlies Anthracolitic limestone.

The Georgetown is a thin formation of marly limestone, marls and clays. Eastward from San Antonio the amount of argillaceous mater increases. The Georgetown horizon can certainly be traced as far to the west as the Burro Mountains

of northern Coahuila and as far south as Lampazos, in northern Nuevo Leon. The oil content of the Georgetown is altogether negligible, at least west of the Brazos.

The Georgetown horizon is represented in the northern Trans-Pecos region by an assemblage of rocks thicker and more diversified than is found elsewhere in West Texas. The El Paso section shows about 500 feet of rocks of Georgetown age. This section is as follows, from base upwards: (1) Marls, gray to yellowish, with thin layers of dark blue limestone, brown sandy limestones, sandstones, black and gray shales, 200-250 feet; (2) Marls, blue to grayish, weathering whitish, 150 feet; (3) Marls, gray and brown, with interbedded limestones and brown sandstones, 70 feet; (4) Sandstone, coarse, heavy-bedded, red, white and yellow. Partly of Del Rio age, 70-300 feet. These are littoral deposits. They may be traced eastward to Fort Stockton and Pecos river, but the water seems to have been somewhat clearer towards the east. There appears to have been considerable sediment coming to the Trans-Pecos sea from either the north or the west or from both directions during both Fredericksburg and Washita. In the southern Trans-Pecos region from the Quitman Mountains to the eastern side of the Big Bend the Georgetown is a pure limestone, of greater thickness than east of the Pecos.

The Del Rio exhibits the same lithology in Texas as far west ab about the west line of Presidio county. The same facies is found in northeastern Coahuila as far west as the Burro Mountains. This facies of greenish-blue laminated clay, with thin flags of shell breccia and some thin clayey limestones near the top thickens towards the southwest (Del Rio and northeastern Coahuila). The Del Rio horizon changes to limestone in the southern Big Bend country, and to the south in Mexico. Near El Paso to the west it becomes more sandy. The terrigenous material of both Georgetown and Del Rio came from land areas to the northeast and northwest. A current may have brought silt to northeastern Coahuila and adjacent parts of Texas.

The Buda limestone has a remarkable uniformity. In most of northern Mexico it forms the upper part of the great moun-

tain maker of the eastern Cordillera, a limestone which attains a maximum thickness of about 3,500 feet and ranges in age from lower Trinity at the base to upper Washita at the top. This great limestone may be largely of reef origin. The Buda is everywhere in Texas a hard, brittle, chalky white, pure limestone. It has a remarkable uniform thickness of fifty feet in its northern outcrops from Austin west, increasing in some places to the southward along the Rio Grande to seventy or eighty feet. It was certainly deposited in clear water. The Buda gradually thins east of Austin and disappears at Brazos river. From the Brazos westward it can easily be followed as far as the Burro Mountains of Coahuila.

Altogether, there appears to be little chance for large accumulations of oil and gas in the Comanchean series of West Texas. The Del Rio is the most favorable formation but does not have the requisite thickness. The formations that are sufficiently thick do not appear to have been deposited under favorable conditions.

In northeast Texas and adjacent parts of Louisiana and Arkansas the Comanchean is probably more favorable. Life appears to have been both more abundant and varied there and the deposits contain large amounts of silt which may have both entrapped and preserved the bitumen. If the conditions there were really deltaic or estuarine they should have been favorable for bituminous accumulation and if perchance such a current as the present Gulf Stream impinged on that coast conditions would have been more favorable still.

THE DAKOTA

The Dakota of the western interior is thought to be represented in the Texas region by light-colored hard and thick quartzitic sandstone 800-900 feet thick near El Paso (Cerro de Muleros), by sandstone outcroping in the northwest Panhandle, and by the Woodbine. Nothing bearing the slightest lithologic resemblance to the Datoka has ever yet been found in Mexico except near Ciudad Juarez. There has also never been found the slightest evidence of an uncomformity, either stratigraphic or faunal, at or near this horizon in Mexico. So far as the writer can recall, marine fossils have

been found in the typical Dakota only at the type locality of Meek and Hayden on Missouri river. In his studies of the Dakota of the Rocky Mountain region he has never found a marine fossil. There are marine fossils in the Woodbine of the western Mississippi embayment region. The typical Dakota contains many remains of land plants and locally thin coal and lignite beds. The Woodbine differs from the typical Dakota in its content of a large percentage of shale. The latter consists of sandstone and conglomerate, often quartzitic, and nearly always exhibiting evidences of extremely shallow water or terrestrial origin. It is possible that the brackish water fossils on Missouri river were deposited in a sea advancing from the north.

There is interval of but a few feet between strata carrying *Ostrea quadriplicata* and the Dakota in the region of Tucumcari, New Mexico. The fossil may range throughout the Washita division, so the Tucumcari beds may belong to the Georgetown or to a later stage of the Washita. Should they not be latest Washita there may be a time break between them and the Dakota. The thick series of sandstones between the Buda and the Benton (Eagle Ford) in the El Paso section has yielded no fossils. There is an interesting contact between Dakota and Benton at several localities just east of Las Vegas, New Mexico. Here the upper surface of the Dakota shows either a shore line or extremely shallow water and the lowermost Benton contains sands apparently derived from the Dakota.

The youngest marine strata prior to the Dakota in western Colorado, western New Mexico, southeastern Utah and northwestern Arizona belong to the lower part of the Upper Jurassic. Overlying this marine Jura is a thick series of sediments, mostly sandstone, concerning the exact age or ages of which very little is known. Some of these sandstones appear to be truly desertic and all may have been deposited under arid conditions. Should they have been eroded they would furnish sands like those of the Dakota and they may have been the source of the Dakota sands. The Dakota both covers these sediments and extends for great distances to the east of them.

It is possible that either a change to greater humidity of climate or slight upwarping may have brought about their erosion and the materials redeposited formed the Dakota. Possibly the Dakota is to a large extent a subaerial deposit. In the region where it overlies marine Washita beds the Dakota may be at least in part marine or its deposits may have forced the recession of the shore line of a shallow sea. If marine, it is puzzling to explain the absence of marine fossils while plant fossils are found in such regions as New Mexico where the Dakota overlies in some places marine Washita beds. The question whether the Dakota may not have been deposited in a temporarily receding rather than an advancing sea is at least pertinent.

THE BENTON

There is strong probability that future work will demonstrate that the Benton had the greatest extent of all Cretaceous seas in the trans-Mississippi region. The great mediterranean epicontinental sea of Benton time extended from the Arctic Ocean to the Caribbean and from near Mississippi river on the east to the Great Basin highland region of Idaho, Utah and Arizona on the west. It must have covered a very large part of Mexico. The source of most of the sediments lay in the Great Basin region, for the deposits thicken and become coarser to the west. Another source of Benton sediments appears to have been the Ouachita and perhaps the Ozark region of Arkansas and eastern Oklahoma.

There appears to have been a north-south current through the middle of the Benton mediterranean. It is likely this current passed through the Austin-San Antonio region where the Eagle Ford sediments are from 25 to 50 feet in thickness and there may possibly have been some submarine current erosion of the underlying Buda in a sea whose bottom was swept nearly clear of sediment. Another possible explanation for the thinness of the Eagle Ford here is that here lay the clearest waters of the Benton sea. Westward the Benton sediments thicken to possibly 400 feet under Eagle Pass. More than 1,000 feet of Benton is found at Lampazos, state of Nuevo Leon, Mexico, and there is something like the same thickness throughout eastern Mexico. There is marked change in the lithology to

the westward and southward from the blue-black shales at Austin and San Antonio to interbedded dark blue thin to medium bedded limestone and marly shales.

In the Trans-Pecos region of Texas and New Mexico the Benton is both thicker and different lithologically than it is east of the Pecos and north of the Rio Grande. In the region between Santa Fe and Albuquerque, New Mexico, the Benton has the characteristic intermontane Mancos phase with shales, thin beds of shaly limestone, possibly even some beds of coal and a marked percentage of sand in its composition. At Las Vegas, New Mexico, the Benton consists of a lower blue-black shale and an upper thin to medium-bedded blue-black fine-grained limestone. In northwestern Colorado the Mancos (Benton and Niobrara combined) has a thickness of 5,000 feet and consists entirely of shale. On the southwest flanks of the San Andreas Mountains, just north of the Texas-New Mexico boundary in the latitude of El Paso the Benton rests directly on the Lower Permian and consists of heavy conglomerates derived from the underlying Permian limestones and sandstones and of red sands and clays probably derived from Permian or Triassic Red Beds. *Inoceramus labiatus* is found in the base of these deposits, which aggregate in thickness something like a thousand feet. Only the lower part of the Benton has been left in the vicinity of El Paso with an exposure of about 150 feet of dark brown to black shales and sandstone with a few intercalated medium-bedded blue-black sandy limestones weathering dark brown. In the Quitman and Eagle mountains there is over 700 feet of dark brown shale with occasional layers of impure limestone. In the Davis Mountains the upper part of the Benton consists of interbedded blue-black shales and limestones, the percentage of limestone increasing towards the top. In the Big Bend country the Benton has the Mexican phase of flaggy limestones containing some sand and clay, sometimes chalky, and from gray and yellowish-white to almost black in color. Its thickness is about 600 feet. In the Trans-Pecos Texas region and in Mexico much of the sediment has the appearance of being foraminiferal in origin. The

deeper and clearer waters of the Benton lay in the Mexican region.

The writer has seen the Benton at various localities between Athabaska river of Canada and central Mexico. He has never seen a section that was not markedly bituminous. Bones of fishes can nearly always be found and it is probable that the microscope will nearly always reveal foraminifera. The shale is very suitable for holding the bitumen but whether it will yield it in large quantities to a well in the Southwest is as yet problematical. Where interbedded sandstones occur there are good storage reservoirs. The interbedded limestones may yield oil upon being shot. Where the Dakota sandstone occurs beneath the Benton a very good storage is available and the overlying Niobrara nearly always contains porous beds in which oil or gas may be stored.

The regions of West Texas affording most promise for oil exploration in the Benton lie in the triangle whose northern side is a line between Uvalde and Del Rio, with the Rio Grande between Del Rio and Brownsville as its southwestern side and its eastern side a line from Uvalde to the Gulf Coast at a point about midway between Brownsville and Corpus Cristi. Other possible producing areas lie in the synclinal region of the Salt Basin between the northern escarpment of the Davis Mountains and the Rio Grande in the vicinity of Terlingua. However, this region is mainly synclinal and contains as well a very great development of igneous rocks.

THE NIOBRARA

Evidence is now fairly well in hand that the earth movements in the Cordilleran region which have generally been referred to the Laramide of the Cretaceous and early Eocene began both in Mexico and the United States about the close of the Benton. The Niobrara in Mexico is represented by a thick series of shales and sandstones. No chalk has been found in Mexico south of a line connecting Monclova and Lampazos. In the Rocky Mountain Intermontane region of the United States the Niobrara has the Mancos phase, with a thick series of shales, generally some interbedded more or less heavy sandstones, and locally beds of coal. In the region east of the

southern Rockies, in southeastern Colorado and northeastern New Mexico, the Niobara contains shales as wel las limestone. In the center of the southern portion of the great mediterranean trough the deposits of the clearer waters were chalk and chalky marls, which appear to be fully ninety per cent of organic origin. The most abundant organisms were probably foraminifera. But the porosity of the chalk and the lack of silt precluded the retention of the bituminous matter. The chalk in general has sufficient porosity for storage of oil and, since it is both overlain and underlain by sediments which retained abundant bitumen, it may yield oil and gas in West Texas.

THE PIERRE

Towards the eastern Great Basin region of the United States the Pierre sediments become increasingly coarser, generally become thicker and have a larger proportion of purely terrigenous materials. The same statement applies to Trans-Pecos Texas and northeastern Mexico. In the central portion of the mediterranean the waters were clearer, the deposits were more marly and less terrigenous and more bitumen was stored up. The marls underlie that part of West Texas south of the Balcones escarpment but become more clayey to the west as the Rio Grande is approached. Marly beds are found also in the Davis Mountains and the Salt Basin syncline but north of the line of the Southern Pacific Railroad they are next succeeded by volcanic tuffs and lavas. In the Tierra Vieja Mountains of Presidio county the horizon is represented by deposits of clays and sandstones. Evidently the land emerging on the west had greatly constricted the Pierre sea.

In the region between the Balcones escarpment, the Rio Grande and the Gulf of Mexico the Pierre (Taylor) is the most important oil and gas producing formation of the West Texas Cretaceous. It has yielded oil and gas at Corsicana, Mexia, Thrall and Somerset. The marls contain large quantities of foraminifera, fishes and other bitumen-producing organisms and the bitumen has been largely retained by the sediments.

The Anacacho limestone of Medina, Uvalde and Kinney counties is a great lens in the Pierre. This limestone has the

appearance of a reef and seems to have been deposited in much the same manner as a barrier reef or a bar of the present day. Near Cline this limestone is porous and is largely a shell marl or coquina containing one of the largest deposits of asphaltic limestone on the continent.

Submarine volcanoes erupted in the Pierre sea in Taylor and Travis counties.

THE FOX HILLS

The approximate equivalence of the Navarro of Texas with the Fox Hills of the Great Plains and Rocky Mountains is shown by the presence in both of *Sphenodiscus lenticularis* and *Exogyra costata*. The Exogyra should be used with caution as an horizon determiner since it is found in the same beds with *Gryphaea vesicularis* in the state of San Luis Potosi, Mexico. In Texas *Gryphaea vesicularis* seems to be most commonly associated with *Exogyra ponderosa* of the Pierre but is also found in the Austin Chalk. The upper limits of the Fox Hills on the Texas side of the Rio Grande are not exactly defined. It is thought that the upper half of the Anacacho limestone and at least part of the Pulliam formation belongs to it, as well as the San Miguel beds and Coal series of the Eagle Pass region. The San Miguel seems certainly Fox Hills.

The Navarro east of Uvalde consists largely of glauconitic marls with beds of impure limestone in their upper part, succeeded by black, bituminous sandy clays. These beds occupy the site of the deeper and clearer waters while the strata to the west of San Antonio become coarser and more detrital and southwest of Uvalde greatly thicken. The San Miguel beds of the Eagle Pass region are sands, clay and shales and the overlying coal series are the same with their added content of workable coal. In most parts of the Mexican state of Coahuila the Fox Hills strata are 2,000 feet or more in thickness and resemble the section at Eagle Pass, with the exception that they contain conglomerates and numerous evidences of times of very shallow water or subaerial deposition alternating with marine and brackish water conditions. In the Trans-Pecos region the Fox Hills is known only in the Big Bend country, where it shows the same composition as the Eagle

Pass and Mexican strata. Evidently the Fox Hills sea was more restricted in area than the Pierre at the same time the Cordillera were growing in altitude and furnishing more sediment.

The Navarro may be suspected of being oil-bearing in the region east of Uvalde, particularly since the Eagle Pass coal beds pass eastward into asphalt-bearing beds.

THE LATEST CRETACEOUS

Beds of Cretaceous age later than Fox Hills are probably found in Texas at two localities along the Rio Grande, near the Webb-Maverick county line and in the vicinity of the Chisos Mountains in the Big Bend country. The Escondido beds of Dumble and Owen contain *Sphenodiscus pleurisepta* and *Pachydiscus* of the group of *P.-colligatus*. The latter fossil is a characteristic ammonite of the Maestrichian of Holland and Belgium, the highest marine Cretaceous yet known. It would seem that the Cretaceous sea may have lingered longer in the Rio Grande region than elsewhere. The Escondido contains conglomerates and its upper part shows that during its deposition the sea stood several times at the shore line. These beds are exposed on the Rio Grande probably because the river has cut farther down into the contact there than elsewhere and removed some of the overlapping deposits of the Eocene.

The Rattlesnake, Tornillo and Chisos beds of the Big Bend, over 3,000 feet in total thickness, may extend into the Eocene. They show evidences of rapid deposition and include all the common types of sediment and in addition volcanic ash. The basal rhyolitic tuffs of the Davis Mountains may be considered as very late Cretaceous if we accept the opinion of the vertebrate and invertebrate paleontologists in preference to that of the paleobotanists. These tuffs were deposited on a land surface of the Pierre.

CLOSE OF THE CRETACEOUS

Very late in the Cretaceous the sea withdrew from the area of outcrop of Cretaceous rocks in Texas. The time break between Cretaceous and Eocene is not great along the lower Rio Grande but an unquestionable erosional unconformity be-

tween the two can be seen on the Mexican side of the river. Farther east in Texas the time break is greater, probably because of a greater overlap of Eocene strata there. Evidence has recently come to the writer that there is evidence of folding and erosion of the Cretaceous previous to the deposition of the Eocene along the flanks of the front ranges of the Mexican Cordillera in the states of Nuevo Leon and Tamaulipas. Should this be true the Laramide uplift affected the Cordillera of eastern Mexico.

CONCLUSION

The Taylor and the Eagle Ford appear to be the most promising formations for oil prospecting in the Cretaceous of West Texas. The Coastal Plain is the most favorable area. In it the structure is controlled by two major lines of deformation, the southward dip of the South Texas Coastal Plain and the eastward to northeastward dip on the flanks of the easternmost Cordilleran Front Ranges of northeastern Mexico. The meeting at approximate right angles of these structural lines forms a southeastwardly plunging syncline followed approximately by the middle course of Nueces river. Between the Nueces and the Rio Grande are some broad low anticlinal folds in the angle between the main structural lines. There are also some anticlinal structures in Zavalla county and southern Uvalde county but these may be open to the north in the area of igneous intrusions and faults. It is barely possible that the Cretaceous may be within reach of the drill in the salt domes of southernmost Texas.

Oil may be found in the Taylor marls and the Navarro in conditions other than anticlinal. There may be porous lenses in these formations which are closed up the dip by impervious marls or clays. Also, the submarine basaltic lavas interbedded with these sediments have sometimes become extremely porous by later serpentinization or by other hydro-metamorphic processes and thus may afford excellent reservoirs for oil or gas.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

THE WISCONSIN SECURITIES LAW

By W. H. Twenhofel

INTRODUCTION

As several documents written by members of this Association have been submitted under provisions of the Wisconsin Securities Law, it will probably be of interest to know such features of the law as relate to securities based on petroleum.

The Wisconsin Securities Law is administered by the Securities Division of the Railroad Commission. Since it went into effect, August, 1919, there have come before it about forty applications for permission to sell the oil and refining securities of organizations, the holdings of which are distributed from Pennsylvania to California, and from Montana and Wisconsin to Louisiana and Texas.

As administered, the promoters of oil and refining companies are divided into three groups: (1) those who wish to sell securities for fraudulent purposes; (2) those who wish to sell securities which can be proved to be valueless either because the promoters do not have the ability to carry out their projects or because their holdings have no hope of production, the promoters, however, being ignorant of their value; and (3) those who promote organizations whose securities are based on real possibilities. The Securities Division seeks to protect the public against classes 1 and 2 and also to protect the promoters of class 2 against themselves. This classification does not exist in the law, but develops in its administration.

CLASSES OF SECURITIES

Securities are classified into those which are exempt from the provision of the law and those which are not exempt from its provisions. The latter are subdivided into Class A and Class B.

Exempted securities embrace those of the nation and its political subdivisions together with similar securities of other

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nations, and commercial or other securities which are commonly exempted in other states.

Unexempted securities belonging to class A are those which are based on established values or income. They embrace under certain restrictions notes or bonds issued by a person or organization which are secured by property, and securities issued by a person or organization owning a going business or industry. Few oil securities come in this class.

Securities belonging to Class B embrace those which are based on prospective incomes. It is this class which interests the petroleum geologist for it is upon his report of the properties of organizations seeking permits that weight will be placed by the Securities Division in its consideration of applications.

APPLICATION FOR PERMITS

Before securities of Classes A or B may be offered for sale a permit must be issued. The application for a permit, in addition to information as to the organization, capital stock, proposed method of promotion, etc., which is commonly required, must include: an appraisal of the company's assets by a qualified person; copies of all leases which the organization holds with opinion from a reputable attorney as to title; exact information showing locations of holdings acquired or under consideration of purchase; present production, if any; initial production of each well with date of coming in; present production of each well; number of dry wells drilled on the holdings; sketch showing locations of all wells; geologic report on all holdings for which there are no published government reports, the geologic report to be made by a qualified geologist of recognized standing;[1] and the relation of holdings to other producing areas.

Refining companies, in addition to the information required from all companies, will be required to present proof that there

[1]In many instances it will be wise to obtain the Division's approval of the geologist before he is directed to examine the properties. Many geologic reports which have come before the Division have been rejected because of their worthlessness. Geologists who are not known to the geologist of the Division must present proof that they are qualified to pass upon the merits of oil properties. The Securities Division does not recommend geologists.

is accessible to them a supply of crude oil sufficient to maintain operation of the proposed refineries. The Securities Division through its permit fixes the price at which the stock may be sold; and, in general, all stock granted for payment of leases must be placed in escrow for such time as may be determined by the Director.

The permit issued to an organization is not an endorsement of its securities but is merely permissive in its effect. If the organization prepare any advertising matter relating to its securities after the permit has been granted, before such advertising matter may be used it must be submitted to the Securities Division and, if not approved, the material can not be used. All subscription contracts used for the sale of securities of class B and every notice or advertisement relating thereto must carry in bold type the statement "THESE ARE SPECULATIVE SECURITIES." If an organization in any way change its articles of organization after the permit is issued or modify its by-laws or plan of doing business, the sale of its securities must cease until such time as it has secured the Division's approval of the changes made. An organization must make reports to the Securities Division at such times as may be required. In these reports there must be stated the amounts of securities sold under the permit, together with such other information as may be required.

Brokers and agents wishing to sell securities of classes A or B must secure certificates from the Securities Division. Application for the certificate must be accompanied by certain required data relating to the standing of the broker or agent and reports must be made to the Securities Division in the same manner as by companies.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

THE RELATION OF MOUNTAIN FOLDING TO THE OIL AND GAS FIELDS OF SOUTHERN OKLAHOMA

By Raymond C. Moore

INTRODUCTION

Location of fields. In the central part of southern Oklahoma, chiefly in Carter, Stephens and northern Jefferson counties, a number of oil and gas producing fields have been developed which are among the most important in the Mid-Continent region. Healdton and Hewitt in western Carter county have been the largest producers but other noteworthy areas are located in the vicinity of Wheeler, Fox, Loco, Waurika, Duncan and Walters. It is primarily with the conditions of occurrence of the oil and gas in these fields and the possibilities of future development in the region that the investigations here reported are concerned.

Problem of subsurface conditions—The surface formation in all of the fields mentioned is Permian Red Beds which are nearly flat-lying and overlap eastward upon the subjacent Pennsylvanian and the older rocks exposed in the Arbuckle Mountains. The oil and gas are in part found in sands in the lower part of the Permian but are chiefly derived from gently folded sands which are believed to belong to the upper part of the Pennsylvanian. This assumption is based in part on the absence of the predominant red color of the Permian deposits in the horizons of chief production, from the association of limestones with other sediments in the non-red oil producing zone and in part from fossil evidence. The structure indicated by careful correlation of the oil producing horizons beneath the surface is somewhat steeper and more sharply defined than that at the surface but the strata are not notably discordant. This is greatly in contrast with the character of the Pennsyl-

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vanian as exposed east of the Permian in the vicinity of Ardmore where the Pennsylvanian beds have very steep inclinations and are overlain with profound unconformity by the Permian. Drilling at Healdton, Loco and elsewhere has shown that Cambro-Ordovician limestones occur only a short distance below the oil producing horizons, so that in some cases the combined thickness of the Permian and Pennsylvanian above these old rocks is less than 1200 feet. Finally, it is to be noted that the geographic position and the outline of producing territory of the different fields strongly suggests a controlling structural relationship which is hardly to be anticipated in nearly flat lying strata. These conditions are very important considerations for the operator in the southern Oklahoma fields and their correct interpretation should be a valuable guide in the development of known producing territory and in exploration for new fields. This is the problem which, so far as available data permit, must be solved.

Field Work—In company with Mr. W. E. Hubbard, geologist in charge of the southern Oklahoma division for the Humble Oil & Refining Company, the writer made a study of field conditions in the critical territory of the Ardmore basin and in the Pennsylvanian area north of the Arbuckle Mountains. All the field data gathered by the geological office of the Company and much information kindly supplied by other operating companies in the field were made available for the investigation herein reported. Acknowledgments for this cordial cooperation are made.

REVIEW OF REGIONAL GEOLOGY

GENERAL STATEMENT

The rock formations exposed at the surface in central southern Oklahoma range in geological age from Pre-Cambrian to Quaternary. The dominant geological feature is the Arbuckle Mountain area where at one time stood a lofty range but which has been so deeply truncated and peneplained that now only its stumps remain. It is composed mainly of Cambro-Ordovician rocks, chiefly limestone, but in parts of the area Pre-Cambrian crystalline rocks are exposed. Overlying the Ordovician with essential conformity of structure are beds of Silurian,

Generalized Section of the Rocks of Southern Oklahoma

QUATERNARY	Alluvium, sand, gravel		
	Unconformity.		
CRETACEOUS	Shale, sandstone, limestone		
	Unconformity.		
PERMIAN	Red Beds, shale, sandstone, conglomerate		
	Unconformity.		
PENNSYLVANIAN	Shale, limestone, sandstone		
	Franks conglomerate		0- 500
	Unconformity		
	Holdenville shale	260	GLENN FORMATION 10,000-15,000
	Wewoka formation	700	
	Wetumka shale	120	
	Calvin sandstone	145- 240	
	Senora formation	140- 485	
	Stuart shale	90- 280	
	Thurman sandstone	80- 260	
	Boggy shale	2000-2600	
	Savanna sandstone	1000	
	McAlester shale	1800-2000	
	Hartshorne sandstone	150	
	Atoka formation	3100	
	Wapanucka limestone	100	
MISSISSIPPIAN	Caney shale		1600
	Sycamore limestone		0- 50
DEVONIAN	Woodford chert		650
	Bois d'Arc limestone		0- 90
	Haragan shale		0- 165
SILURIAN	Henryhouse shale		0- 223
	Chimneyhill limestone		0- 53
	Sylvan shale		60- 300
ORDOVICIAN	Viola limestone		500- 700
	Simpson formation		1200-2000
	Arbuckle limestone		4000-6000
CAMBRIAN	Reagan sandstone		0- 500
PRE-CAMBRIAN	Granite		

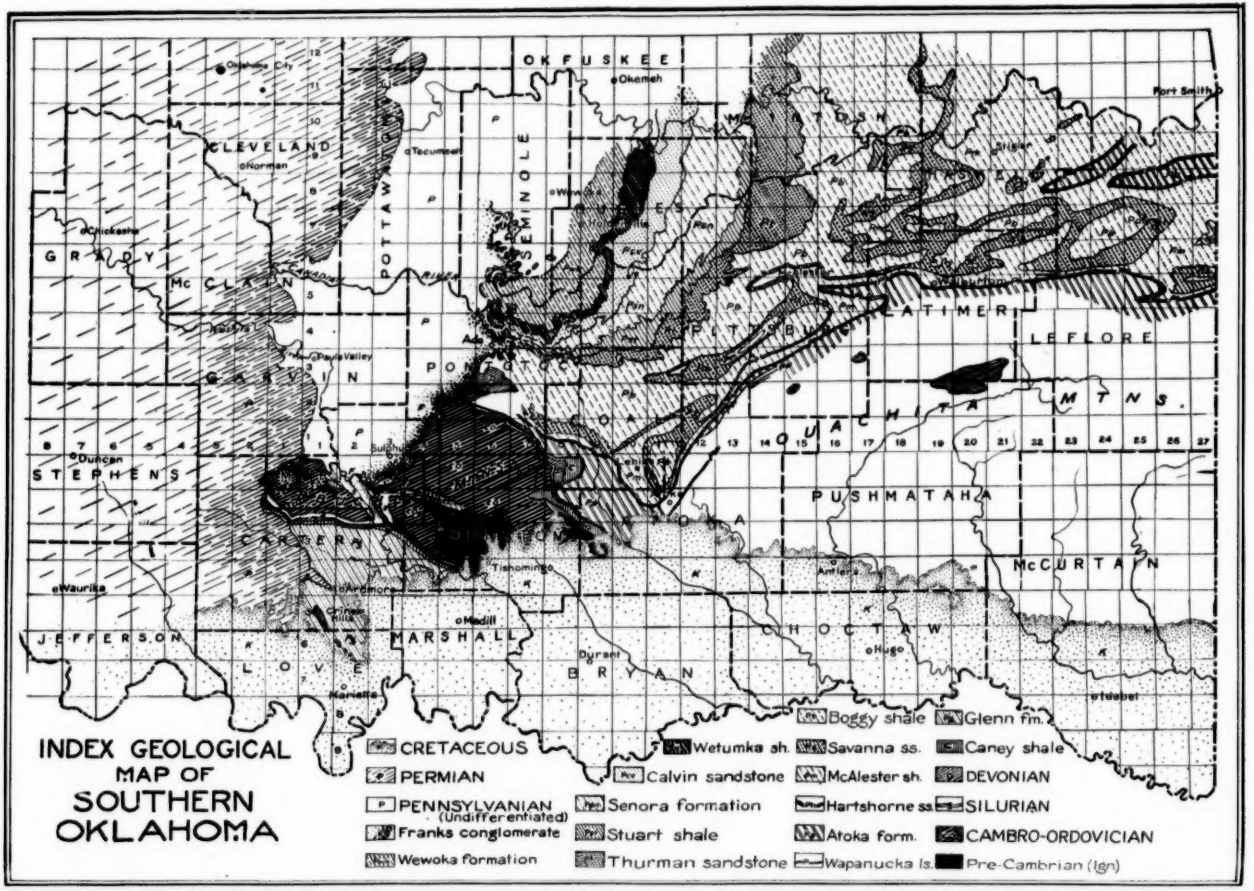
Devonian, Mississippian and Pennsylvanian age. Overlapping the beveled mountain area from the west are Permian Red Beds which conceal all of the older rocks in this direction as far as the Wichita Mountains near Lawton. Both the Permian and older rocks are again overlapped by Cretaceous rocks which extend southward into Texas.

The succession and average thickness of the geologic divisions which are recognized in southern Oklahoma are indicated in the following table. The surface distribution is shown on the accompanying sketch map (Plate 1).

THE ARBUCKLE MOUNTAINS AND CRINER HILLS

The Arbuckle Mountains, the uplift of which comprises a controlling structural feature of central southern Oklahoma, occupy the southern half of Murray and Pontotoc counties, the northern portion of Johnston county and a small area in northeastern Carter county. The central and much the largest portion of the mountain area exposes Cambro-Ordovician and older rocks. Along the margins of the Ordovician on the south and northeast is a regular succession of more or less steeply titlted formations which were originally deposited with essentially parallel bedding upon the underlying rocks. To the northwest, west and southeast, the mountains are overlapped by beds which were deposited subsequent to the uplift and peneplanation of the mountains. Structurally the Arbuckle area is a steeply uplifted mass with sharply inclined borders and a rather broad but irregular central portion which is broken in many places by faults. The axis of the folding trends west northwest.

The Criner Hills lie about six miles southwest of Ardmore in southern Carter county and extending into the north edge of Love county. In them is exposed the same series of rocks, much deformed, which are observed in the Arbuckles. The Hills show on a smaller scale the same conditions as the large mountain area to the north except that the borders are demarked by faulting which conceals the regular succession of some of the beds. The trend of the Criner Hills axis is almost due northwest. The origin and time of uplift of the Criners is identical with that of the Arbuckles and they may be con-


INDEX GEOLOGICAL MAP OF SOUTHERN OKLAHOMA
CRETACEOUS
PERMIAN
PENNSYLVANIAN (Undifferentiated)
Franks conglomerate
Wewoka formation
Wetumka sh.
Calvin sandstone
Senora formation
Stuart shale
Thurman sandstone
Boggy shale
Savanna ss.
McAlester sh.
Hartshorne ss.
Atoka form.
Wapanucka ls.
Glenn fm.
Caney shale
DEVONIAN
SILURIAN
CAMBRO-ORDOVICIAN
Pre-Cambrian (Ign)
OKFUSKEE
CLEVELAND
GRADY
McCLAIN
GARVIN
STEPHENS
POTTAWATOMIE
SEMINOLE
PONTOTOC
COAL
ATOKA
PITTSBURG
LATIMER
LEFLORE
PUSHMATAHA
McCURTAIN
CHOCTAW
JEFFERSON
CARTER
LOVE
MARSHALL
BRYAN
Oklahoma City
Norman
Tecumseh
Okemah
Wewoka
Chickasha
Duncan
Pauls Valley
Ada
Ardmore
Madill
Durant
Hugo
Antlers
Wilburton
Poteau
Port Smith
Waurika
Marietta
Tishomingo
Crimen Hills
Talihina
Stidham
Kiamichi Mtns.

sidered as an essential part of a single orogenic movement.

THE ARDMORE BASIN

The Ardmore basin lies on the south side of the Arbuckle Mountains and includes the area in which the Glenn formation is typically exposed. The Glenn consists of a succession of

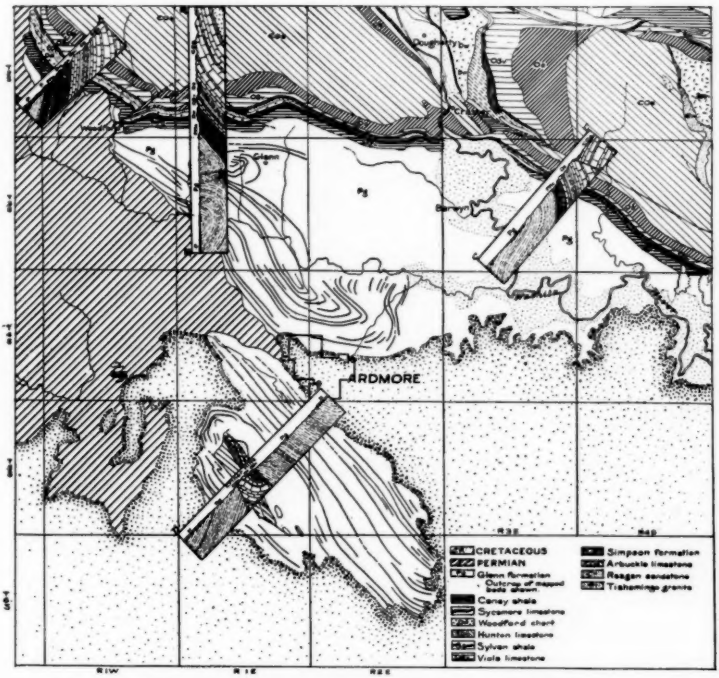


Plate II. Geology of the Ardmore basin with geologic structure sectios. Lines into the area of the glenn indicate outcrops of mapped beds.

shales, sandstones, grits and thin limestones which in lithologic character are not dissimilar from the Pennsylvanian in other portions of eastern Oklahoma. Some of the beds are fossiliferous and the fossils conclusively show that the formation belongs to the lower Pennsylvanian. The basal portion contains a fauna very similar to the Wapanucka limestone northeast of

the Arbuckles and the Bend group of central Texas and may be regarded as equivalent to them. Higher portions represent the Pottsville and all or part of the Allegheny. Goldston[1] has traced in detail the outcrop of many of the mappable beds in the Glenn and has measured a number of stratigraphic sections, from which it appears that the thickness of the formation is in excess of 10,000 and possible as much as 15,000 feet. The beds in the Glenn are steeply folded and conform in their structure to the folding of the underlying rocks in the Arbuckle Mountains and Criner Hills (Plate II). It is very evident that the deformation of the Glenn formation was effected at the same time as that of the Arbuckle Mountain area and that the geological date of the orogenic movement was at least post-Glenn.

The Glenn formation is in parts highly bituminous. Many of the sandstones are impregnated with asphalt which has evidently been formed by the evaporation of fluid hydrocarbons. Without doubt the formation was, and probably still is in part, highly petroliferous. The deep erosion of the parts of the formation which are exposed at the surface in the Ardmore basin has permitted the escape of oil once present here. Where some of the sandstones in the Glenn have been sealed by faulting or where undissected folds in the Glenn still remain within reach of the drill it is very possible that commercial production of oil may be anticipated. In some cases a heavy oil may be found beneath the asphalt sealed outcrops of sands but in these cases the inclination of the beds must not be so great as to carry the sand too sharply downward.

THE CANADIAN VALLEY

In the valley of Canadian river north of the Arbuckle Mountains and extending eastward into the area north of the Ouachita Moutains the Pennsylvanian is represented by a succession of shales, sandstones and limestones which have a total thickness of about 11,000 feet. These, the Wapanucka limestone to Holdenville shale inclusive, are indicated in the foregoing generalized section of the region.

In the vicinity of the Arbuckle Mountains the Wapanucka

[1] W. L. Goldston, Jr., Unpublished MSS.

and succeeding formations are more or less steeply tilted away from the uplift and the strike of the beds changes from a direction nearly at right angles to the trend of the mountains, at a considerable distance to the northeast, to one which is essentially parallel to it near the mountains (Plate 1.) This suggests that the Pennsylvanian of this area was, like the Glenn formation, deposited before the time of uplift of the Arbuckle Mountains and may be equivalent in whole or in part to the Pennsylvanian of the Ardmore basin. Study of the fossils collected from the Pennsylvanian northeast of the Arbuckles shows that this series is all middle or older Pennsylvanian, for the Wewoka fauna which occurs near the top is, according to careful investigations by Girty[2], about equivalent to the Cherokee-Fort Scott horizon in the Kansas section. The fauna of the Wapanucka limestone is almost identical with the observed in the lower part of the Glenn formation. Whether the uppermost part of the Glenn exposed between the Permian and Cretaceous overlaps is as young as the Wewoka and Holdenville formations is not certain, but on account of similar stratigraphic and structural relations to the mountain area, and approximate equivalence in thickness, lithologic character and fossils it seems that the Glenn formation and the divisions northeast of the mountains, Wapanucka to Holdenvile inclusive, are homotaxially equivalent.

After the Arbuckles were elevated into a mountain area erosion not only cut away a great mass of the uplifted rocks but finally reduced the region to a gently rolling plain. Much of the debris, especially of the limestones which comprise the chief rock type in the mountains, was strewn across the eroded edges of the upturned formations. This material, a limestone conglomerate near the mountains, is known as the Franks conglomerate. It is thickest to the west and thinnest to the east; is identified on the southwest flank of the mountains

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[2]Girty, G. H., Fauna of the Wewoka formation, U. S. Geol. Survey, Bull. 544, 1915.
544, 1915. Field work in eastern Oklahoma has traced the Fort Scott-Claremore horizon into the Calvin sandstone which occurs just beneath the Wewoka. The Wewoka may accordingly be regarded as equivalent to a part of the Marmaton formation of Kansas.

[3]Oklahoma Geol. Survey, Bull. 19, Pt. 2, ap of Carter county.

near Woodford and is indicated on geological maps[3] of Carter county east of Ardmore (not observed by the writer). Locally the Franks is interbedded with shale, sand and limestone. At one point in the Mill Creek syncline fossils were found in beds identified by Taff[4] as Franks, the collection containing *Meekella striato-costata*, Derbyas and Productids not found in the adjacent Glenn or northeastern Pennsylvania beds and apparently younger than these. If there was no mountain-making movement in the Arbuckle region until after the deposition of the Glenn and apparently equivalent formations northeast of the mountains, the conglomerates should be found strewn across the beveled edges of the Pennsylvanian as well as the older formations. Detailed field studies under the direction of A. W. McCoy[5] have recently shown that the conglomerates may be traced in a very irregular line northward across central Pontotoc county near Ada into Seminole county where they are found to be identical with the Seminole conglomerate of Taff[6] (Plate I.) Thus it seems apparent that the Arbuckles were uplifted after the time of deposition of the Glenn formation and the Pennsylvanian beds northeast of the mountains, that they were reduced to a peneplain and that gravels were strewn across the eroded edges of the beds. It is very evident in the Ardmore region that all of this preceded the deposition of the Permian Red Beds. North of the Arbuckles it appears that a considerable succession of limestones, shales and sandstones, belonging to the Upper Pennsylvanian follows the Franks. It seems therefore, that the mountain-making and erosion occupy an epoch in mid-Pennsylvanian (Hercynian). As on the north side, Upper Pennsylvanian limestone and other rocks might well be found also on the south side of the Arbuckles. However, the Permian overlaps far to the east and except for one area near Woodford there are no beds which can be identified as possible Upper Pennsylvanian. As will be indicated below, it is believed that some of the rocks found beneath the Permian in the oil and gas fields of Carter and Stephens counties are Upper Pennsylvanian.

[3] Taff, . A., U. S. Geol. Survey, Prof. Paper 31.
[5] Personal communication.
[6] Taff, J. A., U. S. Geol. Survey, Colgate folio.

THE PERMIAN AREA

The country occupied by the Permian is in part nearly flat, unwooded and featureless, and in part marked by sandstone "breaks" or escarpments which in some cases may be traced for long distances. The sandstone country is heavily timbered and very difficult, in general, for geological work. The sandstones, yellow or gray to reddish, are associated with red shales. The strata are nearly flat-lying, with a gentle regional inclination to the west, and locally are found in gentle anticlines and synclines. The Permian overlies with profound unconformity the Glenn formation and the western extremity of the Arbuckle Mountain formations but north of the mountains it is apparently conformable upon the Upper Pennsylvanian. The Post-Glenn Carboniferous limestone and associated strata which overlap the Arbuckle formations west of Woodford have a dip away from the mountains amounting to 3 to 5 degrees, which is steeper than the inclination of the Permian. The thickness of the Red Beds in general increases from east to west. However it is thinner in the central part of the producing areas at Hewitt and Healdton than in the synclinal area, between them, and such relations doubtless obtain in other fields.

SUMMARY OF GEOLOGICAL HISTORY

From the foregoing brief account of the geology of southern Oklahoma it appears that the geological history may be recounted as follows:

During the early part of Paleozoic time a very great thickness of limestone, some sandstone, shale and chert were deposited in the Arbuckle region. Temporarily there recurred times of non-depositions but there was no important erosion and no crustal warping. During the Carboniferous bituminous clastic formations were deposited over the entire region, the total thickness amounting to 10,000 to 15,000 feet. These deposits include the Caney and Glenn formations on the south side of the area at present, and the Caney and higher divisions up to the Holdenville shale now exposed to the northeast. Originally the Caney and succeeding Pennsylvanian beds were probably continuous across the entire Arbuckle region and

their bedding was essentially parallel with that of the subjacent older rocks.

In the mid-portion of the Pennsylvanian the Arbuckle region, including not only the area now commonly designated as the Arbuckle Mountains but all of Carter, Love, Murray, Johnston, and a large number of adjoining counties in southern Oklahoma, was subjected to diastrophic movements which uplifted thousands of feet of sediments folded and faulted them and produced a prominent mountain area. The uplift was probably not sudden and erosion may have removed rapidly parts of the rocks as upraised. The country was reduced to a gently rolling plain and across it was left in places scattered debris, limestone pebbles, sand and mud, resulting from the erosion.

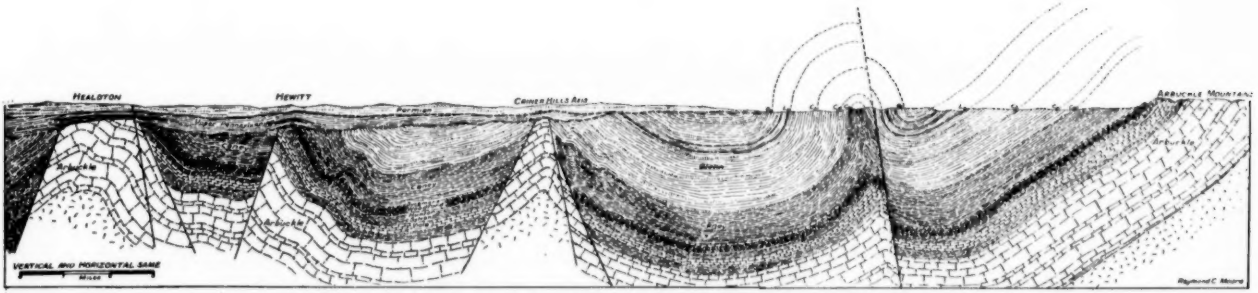
Before the close of the Pennsylvanian, it appears, the sea encroached again upon the Arbuckle region, reworking the products of stream erosion, and forming the Franks conglomerate, succeeded by shales, limestones and sandstones which on the basis of their contained fossils are referred to the Upper Pennsylvanian. These deposits are chiefly exposed in the area northwest of the Arbuckle Mountains. It is probable that they are represented also west and southwest of the mountain area beneath the Permian Red Beds.

In Permian time continental deposits were strewn across the region, without doubt extending originally considerably farther to the east than at present. This overlap nearly completely buried the Wichita Mountains to the west and probably covered the Arbuckles.

After erosion which intervened in the early Mesozoic and which resulted in the partial uncovering of the Permian-concealed Arbuckles and the Glenn area, the Cretaceous seas covered much, perhaps all of the region. Post-Cretaceous erosion has removed a great amount of the Cretaceous deposits and has shaped the present topography of the region.

SUBSURFACE GEOLOGY OF THE OIL AND GAS FIELDS

The conditions beneath the surface in the various oil and gas fields of southern Oklahoma as revealed by drilling and carefully compiled by various geologists are now fairly well



GEOLOGIC SECTION FROM HEALDTON TO THE ARBUCKLE MOUNTAINS.

Plate III

known. The subsurface structure of producing sands has been ascertained, the base of the Red Beds more or less accurately delimited and in at least some of the fields, notably Healdton and Loco, the presence of massive limestone unconformably beneath the producing zone has been determined. These features, together with the rather well defined disposition of the fields in certain trends and the elongation of the producing area in each field in a more or less common direction subparallel to these trends, it is unnecessary to review in detail. The relation of all the observations noted to the regional geologic features, the problems of the source of the oil, and the age of the producing zones is the primary consideration of this paper.

As a typical example of known subsurface conditions in the oil and gas fields of the area, all of the occurrences being fairly closely comparable, Healdton may be described briefly. The producing area at Healdton extends from Sec. 31, T. 2 S., R. 3 W., east southeast a distance of some seven or eight miles into Sec. 24, T. 3 S., R. 3 W. Nowhere is it as much as two miles in width from northeast to southwest and most of the field is little more than one mile wide. The southwest side is very sharply defined and extends in a nearly perfect straight line which has been variously interpreted as a fault, sea cliff along the edge of an old island, steep fold, etc. Since the area of production is elongated considerably in a direction subparallel to trends of the sharp folds in the strata which were included in the Arbuckle Mountain orogeny, it is suggested that there is very probably a genetic relation between them.

It may next be observed that the thickness of the Permian Red Beds varies from less than 500 feet to 1500 feet or more, the former over the highest parts of the structure and the latter along the edges of the structure. Beneath the Red Beds is a zone 700 to 1200 feet in thickness which is essentially non-red and contains some limestone, much blue shale and oil-bearing sandstone. The Healdton oil zone occurs in the lower part of this non-red zone beneath capping blue shale. At depths ranging from little more than 1000 feet at some localities in the northwest part of the field, to more than 200 feet in the

southeast, massive limestone has been encountered in numerous wells. The topography of this limestone surface beneath the oil zone is rather irregular but it conforms essentially with the structure observed in the overlying rocks. Records indicate that the strata in this buried limestone mass are steeply inclined. Ordovician fossils have been identified in cuttings from this buried limestone both in the Healdton field and at Loco. In at least one or two wells deep production of oil is being obtained from Ordovician sandstones, apparently belonging to the Simpson formation.

In short, it appears that Ordovician (and probably associated) formations are brought to within 1000 feet of the surface beneath the Healdton field, and that these older rocks probably underlie the other fields at probably not excessive depths. The top of these older rocks is more or less deeply eroded and their structure is apparently much steeper and quite different from that of the overlying rocks. The latter consist of approximately 1000 feet of non-red oil-bearing rocks and the Permian Red Beds.

ORIGIN OF OIL AND GAS OCCURRENCE

It is apparent that the oilbearing beds in the Healdton field are younger than the Carboniferous (Glenn formation) of the Ardmore basin and the Arbuckle orogenic movement, for the Glenn nowhere so far as known rests on beds older than the Caney and there was no exposure of the Cambro-Ordovician limestones after their burial by the succeeding Silurian, Devonian and early Carboniferous until they were uplifted and deeply eroded in mid-Pennsylvanian time. Since the oil-bearing beds are covered by Permian Red Beds, they must be either early Permian or Upper Pennsylvanian.

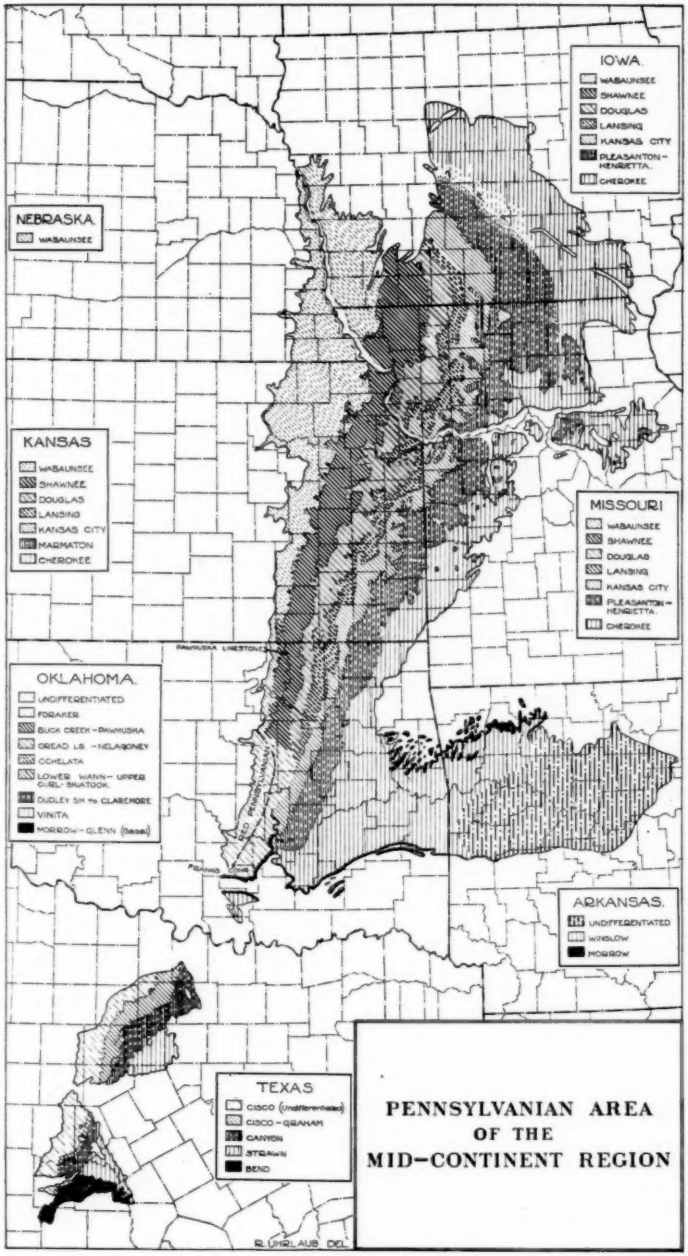
But it is not credible that the great thickness of steeply folded beds which are observed in the Ardmore basin and the subjacent older Paleozoic rocks disappears a short distance west of the border of the Permian. On the contrary these formations and the structures produced in the Arbuckle orogeny must extend westward beneath the surface rocks of Carter, Jefferson, Stephens, Garvin and other counties for many miles. The conditions are probably almost identical

with those now observed in the Ardmore basin, the formations from Cambrian to mid-Pennsylvania being steeply folded and beveled by erosion, and unconformably overlain by late Pennsylvanian or early Permian beds which contain the oil.

The source of the oil is possibly indigenous to the formation in which it is now found, or it may have been accumulated here from underlying bituminous formations. So far as the lithologic character of the oil zone and of most parts of the Upper Pennsylvanian in the Mid-Continent region indicates, it is probably unlikely that the oil originated in the present oil zone wholly. The very large quantity of the oil which has been yielded by such fields as Healdton and Hewitt, the geographic position and alignment of the different fields, variation in gravity and quality of the oil and other features are believed unfavorable to the hypothesis that the oil is indigenous.

It is well known that the lower Carboniferous formations of the Arbuckle region, including the Caney shale, Glenn formation, and the series northeast of the mountains are importantly bituminous. Oil may readily be distilled from the Caney shale and there is an abundance of asphalt, probably derived from the evaporation of petroleum, in the sandstones of the Glenn and in the Pennsylvanian north of the mountains. Also there is known to be asphalt and oil in some of the older rocks of the Arbuckles, as the Simpson. Wells near Dougherty yield a liquid asphalt and very heavy oil, but oil obtained from Ordovician sands in the Healdton field is very good, light in gravity. Since these petroliferous and bituminous formations, many thousands of feet thick and containing huge quantities of the source materials for oil and gas, are without doubt steeply upturned and beveled off beneath the sands and shale of the succeeding Carboniferous which seals them, it would appear natural and probable that the oil and gas have chiefly been derived from these underlying rocks and concentrated in favorable structures in the capping beds.

The origin of the structures in the Upper Carboniferous or early Permian and the succeeding Red Beds may be considered. The fact that the Carter county and adjacent fields



PENNSYLVANIAN AREA OF THE MID-CONTINENT REGION

have rather definite axes and trends has long been noted and it has commonly been concluded that these have something to do with the structure of the region. In so far as the structures observed in the Ardmore basin are persistent and prominent they may be projected along the line of strike of the folds. Such axes as that of the Criner Hills, accompanied by uplift of the older limestones, marked by faults and steeply parallel structure in the Glenn strata, must persist beyond the border of the Permian. There seems to be ample indication that the buried topography beneath the oil zones of the different fields is not unlike that of the present in the Ardmore basin. Above masses, such as the Criner Hills (the position of which is of course determined by the regional pre-Upper Carboniferous folding) structures would probably be developed, both by differential consolidation of the younger beds due to pressure and to slight later movements along these main structural lines. In support of the latter may be mentioned faults which have been identified in the Healdton field, affecting both the lower and higher levels. According to the writer's belief, structures in the beds above the great unconformity should be found along the axes of buried structure in the older rocks, especially where topographic irregularities due to the greater resistance of the old limestones have been developed.

The subsurface conditions and relations, as discussed in the foregoing pages, are illustrated by the cross section (Plate III) drawn across the northern part of the Ardmore basin and through the Healdton and Hewitt fields. The geologic features in the Ardmore basin, and the subsurface geology of the Hewitt and Healdton fields are based on observations—that is, the position and dip of the beds in the Ardmore basin are as shown, and in the Hewitt fields the thickness of the Red Beds and structure of the oil sand zone, and in the Healdton field the thickness of the divisions above the Ordovician limestsone, their structure, and the depth and topography of the buried limestone surface. The structure shown in the Criner Hills axis is an extension of conditions observed to the southeast along the strike. The presence and structure of the Ordovician and associated formations beneath Hewitt are inferred.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

THE RELATIVE AGES OF MAJOR AND MINOR FOLDING AND OIL ACCUMULATION IN WYOMING

By Max W. Ball

INTRODUCTION

The question of the relative ages of major and minor folding in Wyoming has been seriously raised in the past few years in connection with problems of oil accumulation. It has been said that the major anticlines of the region were formed earlier than the minor anticlines; that under the influence of mountain building pressures the greater part of the oil originally in the shales migrated to the sandstones and, prior to the formation of the minor folds, along the sandstones to the crests of the major folds, from which erosion has since removed it; and that the minor anticlines, those beneath which Cretaceous rocks are still present, received only such small remnants of oil as were left over from the principal migrations.

At first thought it is natural to conclude that the minor folds resulted from dying spasms of the mountain-making forces, and that they were formed, therefore, after the major folds before the formation of the minor folds. Further thought, however, has led me to a contrary, though tentative, conclusion. This conclusion, and the reasons leading to it, are here presented, in the hope that discussion may be provoked, and may bring forth facts on which a final conclusion can be based. I want to acknowledge my indebtedness for facts and suggestions to W. van Waterschoot van der Gracht, A. T. Schwennesen, T. K. Harshberger, and E. F. Davis.

The discussion that follows is confined, even where not specifically so stated, to Wyoming east of Green river. The part of the State lying west of that stream in some respects resembles Appalachian more than typical Rocky Mountain conditions, and is not considered here.

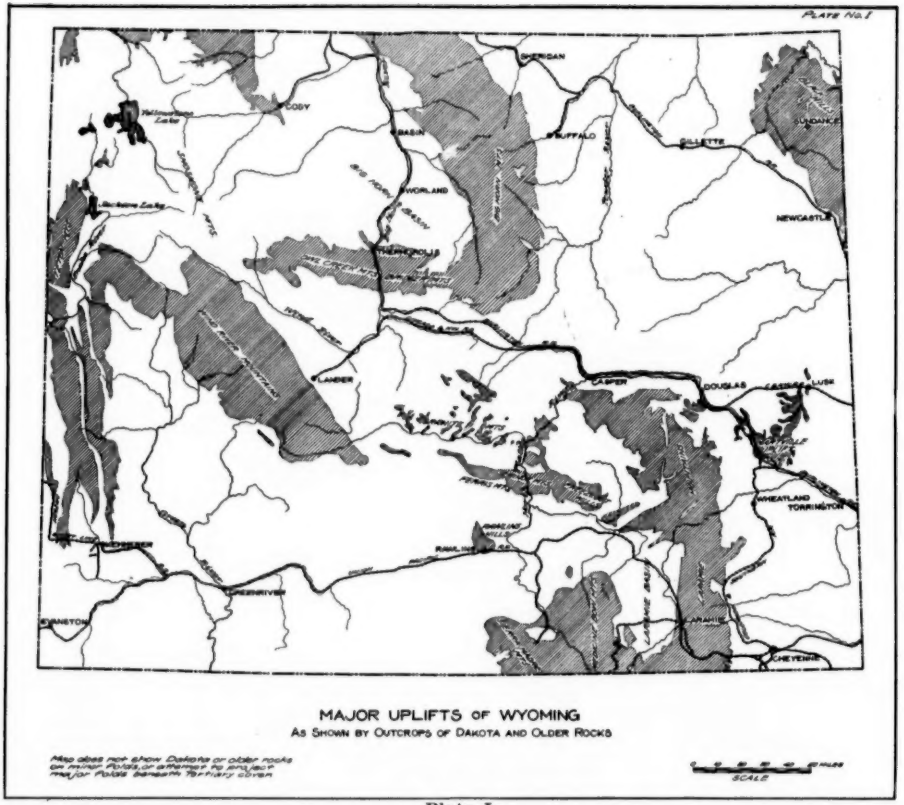


PLATE No. I
CODY
BASIN
BUFFALO
GILLETTE
SUNDANCE
NEWCASTLE
WORLAND
THERMOPOLIS
LANDER
CASPER
DOUGLAS
LUSK
WHEATLAND
TORRINGTON
RAWLINS
LARAMIE
CHEYENNE
MAJOR UPLIFTS OF WYOMING
AS SHOWN BY OUTCROPS OF DAKOTA AND OLDER ROCKS
Map does not show Dakota or older rocks on minor folds, or element by structure major folds beneath Tertiary cover.
SCALE

Plate I

PHASES OF THE PROBLEM

The problem readily falls into two divisions: (1) Were the minor upfolds formed, in whole or in part, after the formation of the major upfolds, and (2), if so, had the formation and migration of oil practically, or at least mainly, ceased when the minor upfolds were formed. Before discussing these questions, however, we should define what we mean by various types of folds.

CLASSIFICATION OF FOLDS

For convenience let us confine our discussion to upfolds or anticlines, and refer to these simply as folds. Obviously what is true of the upfolds will be equally true of the downfolds between them.

We may define major folds (See Plate I) as those affecting a large area, or, perhaps more satisfactorily, as those in which pre-Cambrian rocks have been brought up to an elevation higher than the present level of the adjoining plains. Except for the Rawlins uplift, which affects a relatively small area but in which pre-Cambrian granite is exposed, the two definitions give the same result. All other folds may be classed as minor folds.

Minor folds are, roughly, of two classes, (a) those lying along or constituting prolongations of the axes of major uplifts, and (b) those lying in the "basins" parallel to or at angles to the main ranges.

Probably the clearest examples of the first class, which we may call "axial upfolds," are the folds between the south end of the Big Horn uplift and the north end of the Laramie uplift (See Plate II). Some cause, perhaps the presence or formation of the eastwest Granite, Bridger-Owl Creek, and Shirley-Freezeout uplifts, lessened at this point the forces producing north-south mountain ranges, giving rise to a series of minor anticlines instead of a single great anticline. In this series are the Iron Creek, Oil Mountain, Poison Spider, Pine Mountain, Powder River Station, Goose-egg Mountain, Emigrant Cap, North Casper, and other folds. Perhaps the Tisdale, Castle Creek, Midway, Big Muddy, and Salt Creek folds should also be included, though Salt Creek, and perhaps

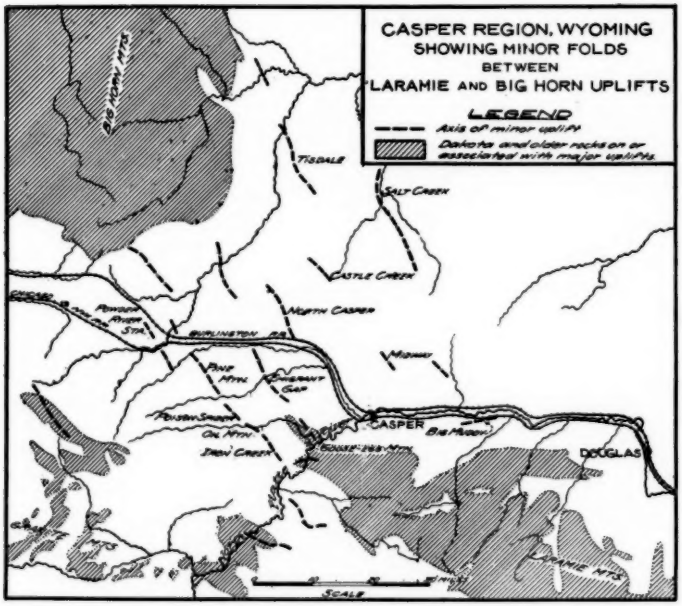


Plate II

the other four, can with equal accuracy be considered as belonging to the second class of minor folds.

The second class of folds, which we may call "basin upfolds," is of two types. By far the most common type has flanks of approximately equal steepness or has its steeper side toward the nearest main uplift, with gentler dips toward the center of the basin. This we may call the "common type." The other type has a gentle dip toward the nearest major uplift and a steep dip toward the basin. We may call this the "exceptional type."

Excellent examples, respectively, of the "common type" and "exceptional type" are the Hamilton and Round Butte folds, shown in cross-section on Plate V.

A typical arrangement of "basin upfolds" is in the Laramie Basin, where some of the folds parallel the major uplifts bounding the basin and some lie at angles to those uplifts (See

Plate III). Another typical arrangement, with all the minor folds parallel to the bounding major folds, is found in the southern Big Horn Basin (See Plate IV).

We have then the following classification of Wyoming upfolds:

Major folds
Minor folds
"Axial upfolds"
"Basin upfolds"
Common type
Exceptional type

GENERAL AGE OF FOLDING

In this part of the Rocky Mountain region mountain-making forces seem to have become active at the close of Cretaceous time, if not slightly before, increasing in intensity during early Eocene to a maximum before the beginning of Wasatch time. They had spent themselves almost entirely before the first half of Eocene time was past, but here and there were slight movements as late as Oligocene time. The earliest Eocene sediments rest on Cretaceous rocks with only slight and scattering evidences of unconformity. The next younger Eocene (Wasatch, Wind River, Hanna) is separated from these oldest Eocene beds by a marked angular unconformity, an enormous amount of folding having taken place meanwhile. Great basins are filled with these younger Eocene beds which lie comparatively flat in the basin centers, but are as a rule tilted somewhat around the edges of the major uplifts, and arched up on the minor folds. The post-Wasatch beds run up to and even over both major and minor folds without as a rule showing more than depositional dips, but in a few places they have been folded slightly. So far as can now be told, all of the folding of Wasatch age or later took place along or near lines of previous folding.

There is evidence, some of which will be suggested later, to show that all of the major folding did not take place at the same time, but that, instead, some of the major uplifts were practically complete by the beginning of Wasatch time, while others were at that time still in process of formation.

RELATIVE AGE OF MAJOR AND MINOR FOLDS

"Axial Upfolds"

Evidently the minor folds of axial type were formed by the same forces that formed the major folds on the same general axes of olding, and it seems reasonable to suppose that the minor and major folds were formed at the same time. Where, as between the Laramie and Big Horn ranges, the minor folds occupy an interval between major uplifts along the same general axis, the minor folds were probably formed at the time of

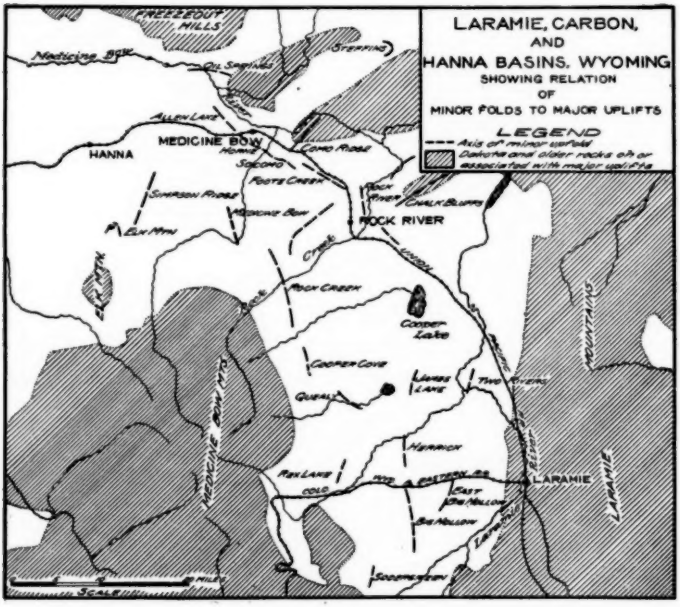


Plate III

maximum folding activity. Where a minor fold lies off the end of a major fold, as, for example, the Buffalo Basin fold lies off the southeast end of the Wind River Mountains, the minor fold may not have been formed until the major fold had nearly attained a maximum height. In the case just cited, the Buffalo Basin minor fold was well advanced and from 3500 to 7000

feet of beds had been eroded prior to the deposition of the Wasatch, but the folding continued into Wasatch time, tilting the basal Wasatch beds to angles as high as 30 degrees. The discordance in dip between adjacent Cretaceous and Wasatch beds varies from 0 to 32 degrees, the axis of folding having shifted somewhat between Cretaceous and Eocene time. In the adjoining Wind River major uplift an additional 8000 or 9000 feet of beds were eroded prior to Wasatch time, and in places the discordance in dip is considerably greater than at Buffalo Basin. Neither the greater erosion nor the greater discordance in dip proves conclusively that the major fold started earlier than the minor; the former may be due to more rapid erosion on the higher fold and the later to greater intensity rather than earlier folding. We can only conclude, therefore, that the Buffalo Basin fold was formed before the Wind River fold was completed, though the formation of the minor fold may not have been until later than that of the major.

This case, perhaps, represents fairly well its type throughout the State, and we may safely conclude that minor folds of the axial type were formed contemporaneously with the major folds along whose axes they lie.

Common Type of "Basin Upfolds"

It is not so easy to fix the relative age of the common type of folds lying in the basins parallel or at angles to the main uplifts. The only marker by which to judge is the base of the second Eocene series (Wasatch, etc.), and these beds do not in many places occupy such positions as to determine relative age. One place where a conclusion may be drawn is on Simpson's Ridge southeast of Hanna.

Simpson's Ridge is a minor fold in the Hanna-Carbon Basin about midway between the Freezeout and Medicine Bow major uplifts. The Hanna formation (Wasatch?) lies on the north end of the Medicine Bow uplift at angles of 4 and 5 degrees, across the edges of older sedimentaries tilted as high as 80 degrees. On Simpson's Ridge the Hanna dips 1 to 60 degrees, which is 5 to 40 degrees less than the older sedimentaries. On the south flank of the Freezeouts the Hanna stands vertical or is overturned in accordance with the older beds. It is evident, there-

fore, that the major folding is not all of the same age. As the Freezeouts are an east-west range, it would appear that in this region the cross stresses did not become active until the main stresses had almost ceased. Perhaps the cross stresses were in large part readjustment tresses from the north-south folding produced by the main stresses. The Simpson's Ridge fold, which lies nearly north and south, must then have been started by the main east-west stresses and completed by the later cross stresses. If so, its initial folding was very likely contemporaneous with the Medicine Bow folding; its final arching contemporaneous with that of the Freezeouts. Here then is a minor fold which began during the formation of the oldest major folding and received added growth during the youngest major folding.

Further field observations may give further examples throwing light on the question, but, in the meanwhile, let us consider what theoretical reasoning would lead us to expect.

The sediments of Wyoming are relatively constant over wide areas. Competent and incompetent beds alternate in the stratigraphic column, but horizontally the variations in competency throughout the State are not important. We can safely assume, also, that the mountain-making stresses were mainly horizontal, or, more accurately, that the horizontal components of these forces were much larger than the vertical components. Indeed there is some reason for believing that the vertical components were almost negligible. From the predominant north-south trend of the main range it is evident that the main horizontal stresses were east-west, but the presence of east-west and diagonal ranges shows that there were cross-stresses.

Now if a considerable thickness of sediments of relatively uniform areal competency were to be subjected to compressive stresses, chiefly lateral, we should expect, should we not, that the beds would begin to buckle in a number of places, especially if the stresses were not all exactly parallel. The first result would be a number of small wrinkles or folds, chiefly normal to the main stress but modified by the cross stresses. We may call this the first stage.

If the pressure were continued, we should expect one of the small folds, through some local variation in competency of beds or some local concentration of stresses, to grow more rapidly than its fellows and become a larger fold. Thereafter it would be the line of greatest weakness along which subsequent

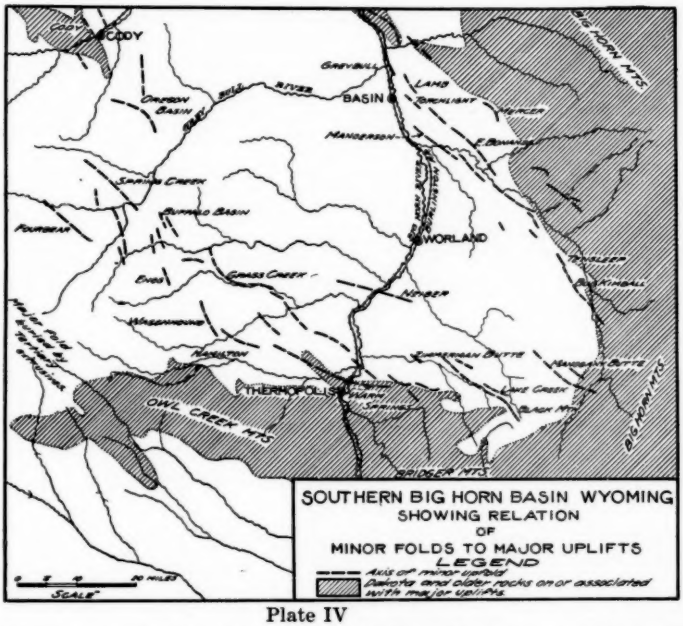


Plate IV

stresses normal to its axis would be relieved. Any further stresses in the same direction would increase the height of this fold, without causing much change in the smaller parallel folds, which, although weaker than the unfolded rocks, would now be stronger than the line of major folding. At the same time any minor folds due to continuing cross stresses would continue to grow at a rate that, depending on relative positions, might be either increased or decreased by the major folding. Thus we should have a major fold, a series of minor folds parallel to it and formed mainly before it attained major proportions, and perhaps a series of minor folds at angles to the

major fold and formed contemporaneously with it. At this second stage, therefore, all the minor folds would be at least as old as the major folds.

If the pressure on the sediments should continue beyond the second stage, the major uplift might gradually become a close fold, and develop into a line of strength instead of a line of weakness. As this took place the continuing stresses would develop a new era of minor folding, probably along the parallel minor folds already started, until one of these folds became a line of maximum weakness, after which it would develop into a major fold and the other parallel minor folds would again become stationary or nearly so. The minor transverse folds would continue their gradual growth unless so situated as to be absorbed in the new major uplift. Thus in the third stage we should have minor folds formed partly before, partly contemporaneous with, and partly after the major folds to which they are parallel, and other minor folds lying at angles to the major folds and contemporaneous with them.

Dr. van der Gracht[1] has caled my attention to a fourth stage which he has observed in inter-montane basins, in which, after the completion of the third stage and the consolidation of the major folds into relatively stable masses, sediments subsequently accummulated in the basins have been subjected to a further period of folding, effecting a compression of the younger sediments into folds generally parallel to the basin rims and not necessarily parallel to the major folds. In this stage the minor folds in the younger sediments are much younger than the major folds or than the principal minor folding in the older sediments.

If this speculative history of folding is correct, what stage of folding is represented in Wyoming? The presence of major folds shows that the first stage is past. That the fourth stage has not been reached is indicated by two factors. First, the few hundred feet of sediments that have been deposited since the main mountain-making movemnets ceased have not, as a rule been affected by later folding. Around the edges of the basins they have, as a rule, been somewhat tilted by continuing

[1]Personal Communication.

movement of the major uplifts, and here and there similar movement of a minor fold has tilted the younger sediments, but nowhere do the younger beds show signs of folding except in connection with movements started long before their deposition. Second, the minor folds in the true basins of the State do not all parallel the basin rims. In southern Big Horn Basin they all lie parallel to the bounding major uplifts; in Laramie Basin they lie partly parallel and partly oblique to the major uplifts, but in neither case do they all parallel the basin rims. (See Plate III and IV).

The absence of closed major folds indicates that Wyoming has not reached even the third stage. Along some of the mountain faces the sedimentaries are steeply tilted and here and there overturned. Faults of some magnitude have been developed, but nearly all of these are normal, not thrust, faults. In general the sedimentaries lie on the flanks of the major uplifts at relatively low angles. The intense flank crumpling of the Appalachians is not present here. With the possible exception of the small east-west Seminoe and Ferris ranges there seems not to be a close major fold in the State.

Thus we may conclude that Wyoming is in the second stage of folding or at most between the second and third stages, and that the minor "basin up-folds" of the common type were formed before the completion of the major folds.

Exceptional Type of "Basin Upfolds"

In the common type of "basin upfold" just discussed either the fold is symmetrical or, more commonly, the dip toward the nearest major uplift is steeper than the dip toward the basin. A few folds in Wyoming and adjacent Colorado, however, have gentle dips toward the mountains and steep dips toward the basin.

If we accept the common assumption that the gentler slope indicates the direction from which the pressure came, then these folds were formed by stresses acting from the mountainward side.

The Horse Creek fold, thirty miles north of Cheyenne, lies just east of the Front or Laramie Range. Along the mountain front west of the structure the sedimentary beds are nearly

vertical, and in places overturned, faulted, or both. On the opposite side of the range the sediments dip at angles of 4 to 12 degrees. If we accept these facts as indicating that the thrust forming the range came from the west, then the Horse Creek structure might have been due to the pushing of the whole mountain mass a short distance toward the east. It is hard to believe, however, that this would take place without much more closing of the major fold than has taken place.

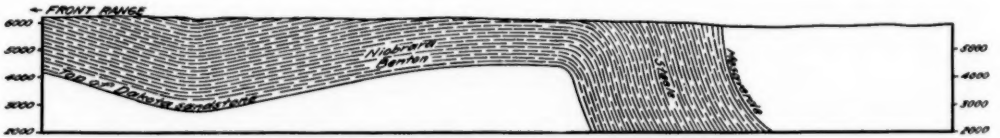
Near Round Butte, Colorado, 30 miles south of Horse Creek, there is a similar fold, with the beds dipping very steeply toward the plains and rather gently toward the mountains (See Plate V). Here, however, the adjacent east flank of the main mountain uplift is rather gently inclined (5 to 25 degrees) and obviously the mountain mass has not been shoved eastward. We may therefore dismiss this possibility from consideration as a cause of such folds.

There remain but two probable causes, assuming that the folds were formed by stresses from the side where the mountains now are; either they were formed by pressures acting prior to the formation of the major uplift, or they were formed by stresses induced by resettling of the major uplift, probably soon after it reached its greatest height. If the first is true, the folds differ from the common type of "basin upfolds" only in that the major uplift developed behind instead of in front of them, and the folds are as old as the major uplift. If the minor folds are due to resettling they were formed after the major fold was well advanced.

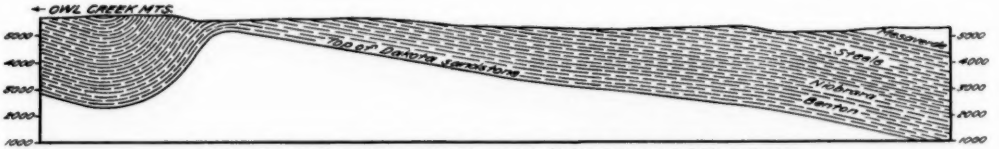
What has been said is based on the assumption that the stresses must have come from the low-dip flank. I am informed, however, by Dr. Davis[1] that experiments by Hobbs and others indicate that in some places the pressure may have come from the steep-dip side. If this should chance to be true here these folds are similar in origin to the common type of folds, and, since the adjacent major uplift is not a closed fold, these minor folds must be considered as old as the major uplift.

Thus, for want of sufficient data, we are unable to fix the relative date of formation of folds of this exceptional type. It

[1]Personal Communication.



SECTION ACROSS ROUND BUTTE DOME
ROCKY MOUNTAIN FRONT, COLORADO
EXCEPTIONAL TYPE OF "BASIN UPFOLD"
(ADAPTED FROM KRAMPERT AND REAM, PRIVATE REPORT.)



SECTION ACROSS HAMILTON (COTTONWOOD) DOME
BIG HORN BASIN, WYOMING
COMMON TYPE OF "BASIN UPFOLD"
(ADAPTED FROM HEWETT AND LUPTON, U.S.G.S. BULL. 656)

Plate V

would appear that they were formed as early as the major fold, by stresses acting from one side or the other, but they may have been formed later by stresses set up by the resettling of the major fold after it had reached a considerable height. It is worth noting that the Arikaree beds (Oligocene) extend undisturbed across the minor folds and onto the major fold.

RELATIVE AGE OF OIL MIGRATION

We have concluded, tentatively, that nearly all, if not all, of the minor folds of Wyoming were formed during the time of formation of the nearby major folds. Even, however, if we were to assume that all the major folds were formed first and all the minor folds later, it would not necessarily follow that the greater part or even a material part of the oil originally present in the rocks migrated to the major uplifts before the minor folds were formed, and thus was subsequently lost through erosion.

The formation and collection of oil involve, first, the distillation of the organic material in the shales of oil; second, the passage of the oil from its point of origin in the shales to the adjacent sandstone; and third, the migration of the oil along that sandstone to the crest of an upfold or other trap. Whether we assume that the oil reaching a sandstone is accumulated from hundreds of feet or from a few inches of shale, the first and second steps undoubtedly take longer than the third, and all of them require long periods of time. Assuming the longest probable interval between folds and the greatest probable acceleration of distillation and migration due to the heat associated with mountain-making movements, it is not likely that migration had proceeded far before the latest folding took place. This would, of course, be pure speculation if it were not borne out by a well-known fact; namely, that the folds lying farthest out from the major uplifts contain the most oil, other things being equal.

If the major folds had been formed first the minor folds next to them would doubtless have been formed next and those farthest away from the major folds last. If oil migration were under way in the meanwhile the major folds should have accumulated the largest quantity; those nearest them the next

largest quantity; those farthest out the smallest quantity. The amount of oil accumulated would vary directly with the relative age; inversely with the distance from the major fold. If, on the other hand, all the folds were formed at or about the same time and oil migration had not progressed far before the formation of the last fold, the outermost folds, being accessible to the basins supplying the oil, would accumulate the largest quantity, and those folds secluded behind these basin-ward folds would accumulate only such quantities as their more limited drainage areas could supply. This is the exact condition shown by drilled wells. The basinward folds, if otherwise favorable, are rich in oil or gas; the inner folds contain much smaller quantities or none at all. Clearly the minor folds were formed before oil migration along the sandstones was well under way.

CONCLUSIONS

Theoretical reasoning, supported by a few observed facts, leads to the following conclusions, advanced tentatively and subject to revision as further folds are developed:

(1) Nearly all the minor folds of Wyoming were formed during the period of formation of the major uplifts.

(2) Nearly all the minor folds of Wyoming were formed before the migration of any considerable quantity of oil.

(3) The minor folds received their relative shares of the oil formed, the amount in each case depending on the richness of the source, the drainage area, and circulation conditions.

(4) If some Wyoming folds have proved disappointing other reasons must be sought than the relative ages of folding and oil migration.

THE METAMORPHIC ROCKS OF WOODSON COUNTY, KANSAS

W. H. TWENHOFEL AND E. C. EDWARDS

INTRODUCTION

The metamorphic rocks which are described in this paper occur in southern Woodson County, Kansas, at a place known as Silver City, situated about four miles west and one mile north of Buffalo in sections, 28, 29, 32 and 33, T. 26 S., R. 15 E. Another possible occurrence of metamorphism is about a mile west and a half mile south of the village of Rose and eight miles south of the town of Yates Center in sections 13 and 18, T. 26 S., Rs 15 and 16 E. The two localities are about five miles distant from each other.

The general structure of the region is that of the westwardly dipping monocline of east Kansas on which are superimposed small anticlinal and domal structures with the characteristics peculiar to that portion of the state. For assistance in the mapping of the structure the writers are indebted to Messrs. F. M. and M. D. Stryker and W. L. Ainsworth. The work was done during the field seasons of 1915 and 1916. The writers are also indebted to Dr. Sidney Powers and Mr. V. H. Hughes who very liberally provided data collected in the region since 1916 and made possible the examination of samples from a well drilled under the direction of Mr. Hughes.

THE SILVER CITY OCCURRENCE

The metamorphic rocks of Silver City are on the north side of a pronounced elongated dome and have their center around a small northward trending nose on this dome. Northward from the locality of metamorphism the sandstones which form the surface rocks have a very red color. This may also be related to the metamorphism. The topography over the dome is that of a basin which is nearly surrounded by rather high hills, of which the summit rocks belong to the Lawrence shale member of the Douglas formation, Upper Pennsylvanian. The outcrop of metamorphic rocks occurs along the south slope and over the top of the ridge which margins the basin on the north.

Plate II. Brecciated and replaced Iatan limestone from Silver City. The fragments are chlorite chert. The cement is hornblende and chlorite.

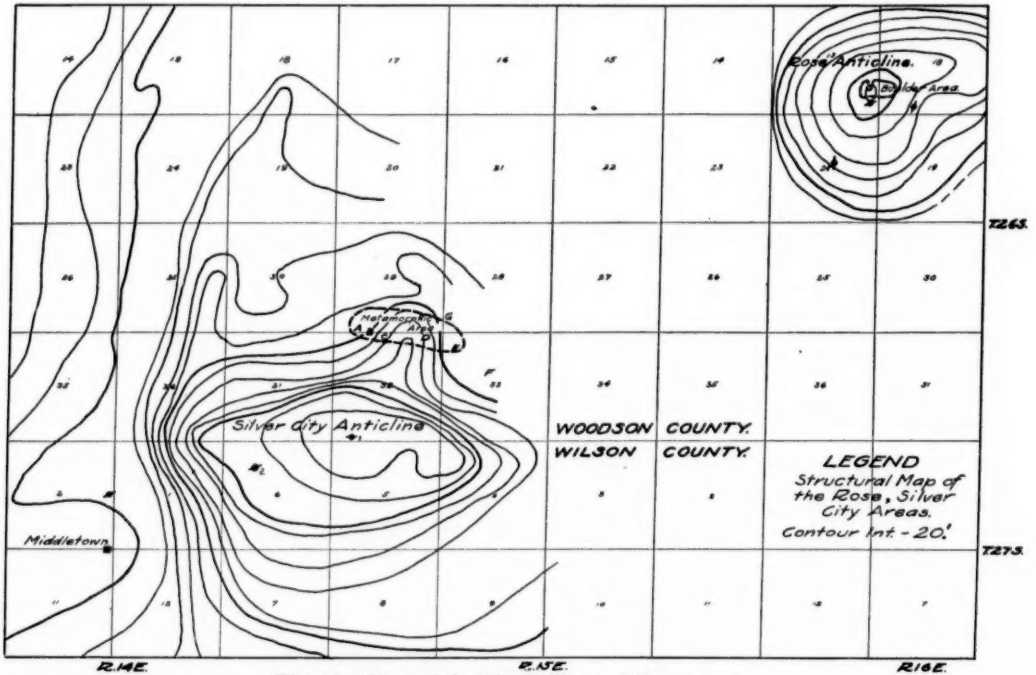


Plate I. Map of the Silver City and Rose areas.

This ridge is the site of Silver City, so-called because of its once having been the location of a tent and shack camp which was called into existence by the reported finding of silver in the metamorphic rocks composing parts of the hill. Along the south side of the top of the hill are several excellent cold-water springs. Since the rocks are inclined northward from the springs it is probable that the water rises along fractures. A fault is said to occur in section 2, T. 26 s., R. 14 E.[1] and it is probable that there is a genetic connection between this fault and the fractures present in the hill.

Geologic Section. The geologic section from the base upward consists of the Stanton limestone member of the Lansing formation and the Weston shale, Iatan limestone and Lawrence shale members of the Douglas formation.

The Lawrence member consists of interbedded shales and sandstones. The bedding of the latter is lenticular and irregular. The colors of the sandstones vary from gray through yellow to brown, the colors of the shales from gray to black.

The Iatan limestone has an upper layer which is hard, brittle and of splintery fracture. It is characteried by a vertical jointing and, for a thin layer (about two feet), its horizontal distribution is remarkable. The lower portion of the Iatan is variable in thickness and composition and generally contains considerable shaly material. In the vicinity of Silver City the thickness of this member is about ten feet.

The Weston shale is variable in its stratification and material. It contains less sandstone than the Lawrence shale and at, or just above, the base there are about eighty feet of black carbonaceous shales which are apt to have a slaty aspect because of excellent primary lamination planes. The member is known to be 204 feet thick in section 24, T. 25 S., R. 15 E.

The Stanton limestone is exposed over the floor of the basin. The rock is a brown-spotted gray limestone. The bedding of the exposed strata is irregular.

Description of the Metamorphic Rocks Within the metamorphic area as outlined on the map the Lawrence shales and sandstones are hard, compact, greenish colored quart-

[1]Powers, Sidney, Letter of November 1, 1920.

zites which locally contain cavities lined with quartz and pyrite. In the sunlight a fracture surface sparkles brilliantly and it is probable that it is this characteristic which suggested that the rock contained silver. Thin sections show that the rock is composed of quartz with a small percentage of chlorite, the latter mineral being most abundant in the fine-grained, thin-laminated portions.

The upper layer of the Iatan limestone is of normal character at the point marked A on the map. Just east of the point marked B the cracks in the limestone are filled with hard black chert while at the point C the limestone has been brecciated and replaced by greenish black chert, the replacement being accompanied by a thickening of the bed. A thin section of the rock filling the cracks in the limestone shows that it is nearly pure chert, but where the chert has completely replaced the limestone considerable chlorite is present. At the point D the limestone is of normal character. At the point E it is thoroughly brecciated; the fragments are completely replaced by greenish chert and are held together by a cement composed of hornblends and chlorite. The fragments in most instances are of light color about the margins and in some instances this color extends to the centers. Thin sections show that the light portions of the fragments consist largely of opal while the green parts contain chert together with needles and laminae of chlorite, golden-yellow to brownish and brownish-gray epidote and rare hornblende. At the point F the alteration of the limestone is initial while at the point G the rock is normal and northwest from the point G there is no alteration.

The sandstones of the Weston shale member are represented in the metamorphic area by thin-laminated, fine-grained greenish quartzites. The basal black shales may have undergone some alteration, but it is not megascopic and no secondary cleavage is known to have been developed. They are not exposed except near the borders of the metamorphic area. The senior writer was led to the conclusion that these shales as observed in their exposures had not been affected, as he has seen shales of a similar appearance in places where it is known that no metamorphism has occurred.

At the time of the supposed discovery of silver in the Silver City ridge several shafts were dug and Mudge states[2] that in the deepest shafts the sandstones "assumed the form of bluish-green chert" which was "traversed by veins of quartz." These shafts had evidently been sunk to the horizon of the Iatan limestone. Hay[3] considered the chert a "true igneous rock," a view in which Mudge did not concur. A great deal of debris from these shafts lies scattered over the surface and none of this is of igneous origin.

Under the direction of the senior writer a well was drilled on the apex of the Silver City anticline (point marked 1). The Mississippian limestone was reached at a depth a little greater than 1300 feet. Except for a flash of a couple of million cubic feet of gas from one of the limestones encountered in this well, it came in dry. A second location was made by Mr. E. M. Stryker at the point marked 2. This also came in dry. No igneous rocks were encountered in either well, but the drillers constantly complained that they were drilling in rocks with which they were not familiar. In each well rocks were penetrated which the drillers identified as mica. This proved to be fine grained sandstone containing a great deal of partially altered detrital mica. "Black limestones" were also encountered. These were found to contain no lime, but appeared to be black shales containing considerable chlorite. Both the micaceous rocks and the chloritic black shales had a soapy feel. It is obvious that the metamorphism extends to great depths and with depth for greater distances from the Silver City ridge.

The Causes of the Metamorphism In the original article relating to the Silver City occurrence[4] the metamorphism of the sandstones and limestones was referred to ascending hot solutions and that coincident with, or antecendent to, the ascent of these solutions, the rocks of the locality of metamorphism had been fractured in which movements the extremely brittle Iatan limestone had been brecciated. No revision of this conclusion appears to be necessary. The source of the hot

[2]Mudge, B. F., Trans. Kansas Acad. Sci., Vol. VII, 1881, p. 12.
[3]Hay, Robert, Trans. Kansas Acad. Sci., Vol. VIII, 1882, p. 17.
[4]Twenhofel, W. H., The Silver City Quartzites, Bull. Geol. Soc. Am., Vol. 28, 1917, pp. 419-430.

solutions was not suggested in the original paper, but since it has been shown that intrusions have occurred in other parts of Kansas and Oklahoma which are underlain by the flat-lying Pennsylvanian strata,[5] it is quite probable that an intrusive igneous rock may lie beneath the Silver City Ridge.

A POSSIBLE OCCURRENCE OF METAMORPHISM AT ROSE

The geologic section in the vicinity of Rose is like that at Silver City. The structure is that of a pronounced dome which here coincides with the topography, so that the highest point on the surface is essentially the top of the dome. The rocks capping the dome are the black shales of the Weston member.

On the north flank of the hill and near the apex of the dome are large and small, coarse grained granite porphyry bowlders Associated with the granite bowlders were seen a few composed of chert and greenish quartzite. Some of the granite bowlders are of large dimensions, one having a diameter exceeding seven feet. Several of the bowlders were dug from their resting places and all of these were found to rest on black shale.

On the road near the school house in the southwestern corner of section 18 there are small quartz veins in the rocks outcropping along the sides of the drainage ditch.

The Occurrence of Altered Rock at Rose No such alteration was seen by the senior writer in the rocks at Rose as occurs at Silver City and he has been inclined to the view that no metamorphism is evident. The black shales were carefully examined a number of times during the summers of 1915 and 1916, a special trip being made in late August of 1916 for the particular purpose of seeing if any metamorphism was evident. The shales were carefully compared with those at Silver City and other black shales from Kansas and elsewhere and it was concluded that the shales carry no macroscopic evidence that they have undergone metamorphism other than that which is related to the ordinary processes of consolidation. Particular search was made for red and

[5]Moore, R. C., and Haynes, W. P., An Outcrop of Basic Igneous Rock in Kansas, Bull. Am. Asso. Pet. Geol., Vol. 4, No. 2, 1920, pp. 183-187.
Snyder, L. C., Oklahoma Geol. Surv., Bull. 24, 1915, pp. 51-53.
Drake, N. F., Proc. Am. Phil, Sec. Vol. 36, No. 156, 1898, pp. 338-342.

chloritized shales, but without success. The shales seen were black carbonaceous shales in every exposure. The cleavage of the shales is slaty. However, the cleavage observed is not due to secondary development, but to primary bedding planes. During the past year a letter was received from Dr. Sidney Powers[6] which stated that one of his assistants had found metamorphic rocks beneath the bowlders which "show precisely the same metamorphism as does the Silver City erea." A letter from Mr. V. H. Hughes gave the information that the "shale with which the bowlders are more or less closely associated is distinctly metamorphosed. In the test drilled, some of the material penetrated between the depths of 1190 feet and 1250 feet also shows evidence of metamorphism[7]." It is probable that new exposures of these shales have been made since they were last seen by the senior writer, but unless the evidence of metamorphism is that of their local chloritization, baking to a red color, or the development of secondary cleavage, the writers will reserve their conclusions relating to metamorphism

The Origin of the Bowlders. In previous papers by the senior writer[8] four hypotheses relating to the origin of the bowlders were examined of which two will be considered at this time. The hypothesis that the bowlders were deposited from floating ice, the deposition having occurred in Pennsylvanian time, seemed to accord best with the facts as they were known and understood at that time. The other hypothesis related the boulders to an intrusion whose weathered outcrop was indicated by them. It was pointed out that the small quartz veins and the distribution of the bowlders are in harmony with the view of an intrusion, but that both of these features are possible of other interpretation. A fact which was not completely appreciated is the occurrence of the greenish quartzite bowlders. These bear a great resemblance to those of the Silver City area and their presence may be explained as being fragments which have remained from the

[6]Powers, Sidney, Letter of November 10, 1920.
[7]Hughes, V. H., Letter of December 23, 1921.
[8]Twenhofel, Granite Bowlders in the Pennsylvanian of Kansas, Am. Jour. Sci. XLIII, 1917, pp. 363-380; Additional Facts Relating to the Granite Bowlders of Southeastern Kansas, Ibidem, Vol. XLVIII, 1919, pp. 132-135.

erosion of Weston and Lawrence shales which once overlay this region and which may have undergone metamorphism similar to that at Silver City. The chert bowlders may have been similarly derived, but as the Oread limestone is the first chert-bearing member, occurring between two and three hundred feet higher, this is less probable.

Early in the summer of 1920 a copy of a letter to Mr. E. DeGolyer was sent to the senior writer by Doctor Powers. This letter gave the information that a "dacite dike" had been penetrated in a well drilled near the middle of section 24, the test having been made under the direction of Mr. V. H. Hughs. At the request of the writers samples of the cuttings from the well were courteously submitted, these being taken at approximately five foot intervals beginning at 1180 feet and extending to 1250 feet. In addition Mr. Hughes advised that "the last thirty feet of rock penetrated drilled extremely hard. The driller was able to average less than six inches of hole per hour and the drill had to be sharpened for at least every two feet of hole made."

The thirteen samples were microscopically examined in detail by the junior writer and several of the samples were also examined by Dr. A. N. Winchell. The prelimary examination showed that calcite is so abundant in all of the samples as to obscure other minerals which may be present. This undoubtedly came from some of the limestone beds which were penetrated. Fragments of fossils were seen in some of the calcite fragments. Because of the large quantity of calcite and its high index of refraction it was deemed advisable to remove this mineral before undertaking the study of others. This was done by treating with hydrochloric acid. The concentrates were then further examined.

As a result of the examination it was found that each of the cuttings contain the following named minerals in varying quantities; calcite, chert, quartz, pyrite and small quantities of organic amorphous and optically inactive material. Calcite is the most abundant. Chert is also relatively abundant, particularly from the deepest cuttings. Quartz is present in each of the samples, but is quantitatively unimportant. In the sample from the greatest depth quartz is well represented. It

appears highly probable that some of the quartz is of sedimentary origin. This statement takes into consideration the undoubted corrasive effect of the churning motion of the drill and is based entirely upon the occurrence of fragments which remain as clusters of rounded quartz grains in their original relationships to each other.

One of the envelopes containing a sample gave the information that in washing mica floated away. This would be apt to be the case, but as mica is a common constituent of a great variety of both igneous and sedimentary rocks and as nearly every sand member of the Pennsylvanian sequence carries some layers in which detrital mica is an important constituent, its presence can be given no significance.

It of course follows that these samples have been washed and the question naturally arises as to their disclosing the true character of the rock penetrated as the churning action of the drill would grind the softer minerals to powder and they might be lost in washing the samples. Most igneous minerals, however, are not soft minerals and this is particularly true with respect to the feldspars which are important constituents of dacite. The feldspars are not so soft as calcite which is present in quantity in every sample and it is quite certain that if any feldspars were present in any rock encountered they would certainly be represented in the cuttings. There is also nothing in any of the cuttings which suggests metamorphism of the sediments. It is not likely, however, that this would be well shown. One of the letters which was received stated that the rock "was red in color" immediately above the reported dike. This would have no significance unless it was known that the same stratum was not red a short distance away.

The reported dike was said to be of dacite. This is an igneous rock of microscopic texture of which the individual constituents can not be identified by megascopic means. It is composed of quartz, orthoclase, plagioclase feldspar of a more sodic than calcic variety and various subordinate minerals which may or may not be present. The study of the drill samples furnished the writers have failed to show any evidence that an igneous rock of the above, or any type, had been encountered and they are forced to the conclusion that no igneous

rock was penetrated by the drill, and further, that the facts known to them strongly suggest that the supposed igneous rock is a chert or very cherty limestone. Drilling in this would be as difficult as in dacite. As the well from which the cuttings were derived was begun on, or near, the top of the Stanton limestone, the Mississippian limestone should be encountered between 1300 and 1350 feet and the presence of what is apparently a very cherty limestone above 1250 feet suggests that the drill found a hill on the pre-Pennsylvanian surface.

There could be little connection between a dacite dike and the bowlders on the surface as the two types of rock require somewhat different contributing magmas and such a connection would be rather contrary to the general rules relating to the crystalization of magmas. Ordinarily an igneous rock is fine-grained when formed at the surface and more coarsely crystalline when formed at great depths. It would hence follow that there could be little genetic relationship between a dacite dike at 1200 feet and a coarse-grained granite at the surface.

Summary of Data Relating to the Rose Occurrence—The summary of data may be made as follows:

(1) The area of metamorphic rocks at Silver City is parallel to the area of bowlders at Rose.

(2) There appears to be a definite alignment in a northeast-southwest direction of the fault in section 2, T. 26 S., R. 14 E., the metamorphic area at Silver City and the area of bowlders on the Rose dome. Faulting and fracturing have occurred in the localities first named and this line of dislocation may be continued to the Rose dome. In the Silver City area it is probable that the fracturing has genetic connection with an igneous intrusion.

(3) Quartz veins occur near the vicinity of the granite bowlders. These quartz veins may indicate the effects of the risings of hot solutions and may indicate the possibility of other igneous effects in the vicinity.

(4) The black carbonaceous shales on the summit of the Rose dome are "slaty." No secondary cleavage has been reported. The writers are not aware that any chloritization or any baking of the shales to a red color has been noted. Hughes

and Powers have stated that metamorphic rocks occur associated with the bowlders.

(4) Quartzite bowlders occurring with those of granite may represent altered Weston or Lawrence shales which once lay over the area, a condition which would parallel the conditions at Silver City and essentially prove an intrusive origin for the bowlders.

(6) Several wells have been drilled on the Rose dome. The logs of several of these have been seen and from none of them has an igneous rock been reported with the exception of the one near the middle of section 24 in which a "dacite dike" is reported to have been penetrated. Examination of cuttings from this well taken at approximately five foot intervals from 1180 to 1250 feet failed to show any evidence that an igneous rock had been encountered.

GENERAL CONCLUSIONS

(1) A small area of metamorphic rocks occurs at Silver City. The metamorphism is considered to have been produced by ascending hot solutions which are assumed to have originated from an intrusion into the rocks beneath.

(2) Granite prophyry bowlders of coarse grain occur near Rose associated with black carboaceous shales which are reported to exhibit metamorphism. Quartz veins occur in some of the rocks of the immediate vicinity. The facts may be explained on the hypothesis that the bowlders mark the weathered outcrop of a dike. This hypothesis involves the acceptance of the view that metamorphiam has occurred. On this point conclusion is reserved.

(3) A study of the drill cuttings from the well near the center of section 4 failed to show that an igneous rock had been encountered. The evidence suggests that the drill had penetrated a cherty limestone forming a hill on the pre-Pennsylvanian surface.

(4) In previous papers by the senior writer relating to the Rose area the bowlders were explained on the hypothesis that they had been deposited by floating ice, the deposition occurring in Pennsylvanian time. If metamorphism have occurred in the rocks on the apex of the Rose dome this hypothesis is greatly weakened.

THE HUMIC ACID ORIGIN OF ASPHALT

By J. D. Haseman

INTRODUCTION

The hydrocarbons of crude oil may have been synthesized from various materials in more than one way. But plants are here considered the chief, if not sole, origin of the hydrocarbons of crude oil, and it is the purpose of this paper to record some data obtained from the examination of certain swamp materials which indicate that asphalt is a derivative of humic acid.

LOCATION AND CHARACTER OF THE MATERIAL STUDIED

The first material examined on a large scale is at Haseman, Florida which is on a bluff of Chotawhatchee Bay about 60 miles east of Pensacola. This deposit was thoroughly examined between November, 1914 and 1918. The next material of commercial value investigated is three miles west of St. George, Charlton county, Georgia.

The Material at Haseman, Fla.—The material at Haseman is in the form of a hard-pan which is black and solid when it is wet and which is brownish and crumbles when it is dry. The deposit extends out from underneath the twenty foot bluff of beach sand into the blackish water bay, and it is almost surrounded on its rear or land side by a large freshwater lake and freshwater swamps. The sandy soil overlying this deposit supports a stunted growth of spruce pines, black jacks, dwarf oaks and large quantities of long slender rooted saw palmettoes and sand also underlies the deposit.

The material is composed chiefly of sand (80 to 90 per cent), but it also contains 5 to 20 percent of organic matter, traces of clay, and a number of minerals such as ilmenite, rutile, zircon, monazite, etc. The material somewhat resembles wurtzilite but it is not a true fossil asphalt.*

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*This material has no name but Dr. L. Lavenden and several of my friends have called it *hasemanite* because the writer manufactured sap brown out of it and because six of his brothers are also interested in various branches of science.

The material is often in two and even three layers in a given area, and the layers have sand partings. These layers are evidently associated with the high and low levels of the underground water, and frequently these layers seem to run together and form hard knobs as much as 8 feet in thickness, but as a rule the layers are not over 2 feet thick. There are also many parallel series of hard bands or ribs of the material extending in the same general direction out of the layer. These ribs are richer in rutile, ilmenite, zircon, monazite, etc., or black sand minerals, which may have been important electrolytic agents in the precipitation of humic acid to form this material.

The commerciably valuable organic material present in the deposite at Haseman can be either washed or dissolved out of the sand. It is soluble, however, only in alkalies and precipitated by acids. When pure it burns, leaving no ash. It is a non-conductor of electricity and a poor conductor of heat. It is an important stain for paper pulp and is used in paints. It has about 53 percent carbon, 44 percent of which is fixed, 3 percent nitrogen, and it yields gases when heated in a closed retort.

The following materials have been found in the deposit at Haseman. Iron, manganese, silica and at least fourteen black sand minerals; tannic, ulemic, lignitic, humic, azo-humic, and azo-silico-humic acids; peat, black, jelly-like material or dopplerite, brown wood-jelly, decayed vegetation, lignite, cassel or van dyke brown, and asphalt; methane, hydrogen sulphide, and other gases.

The dopplerite was in most places found in long slender limb-deposit at Haseman can be either washed or dissolved out of masses. The asphalt was found in thin flat layers. It was completely surrounded with hasemanite and so located that it evidently was synthesized *in situ* and is not drift or seep material. In fact, both dopplerite and asphalt were found above and below the level of the sea in several places and they were more common in a grade of hasemanite which was not first class for the manufacture of sap brown.

The geological age of this deposit is evidently post-Colum-

bian because there was dug up with a steam shovel, a portion of a mast of a schooner which had a piece of lag screw and a square iron nail in it. It was eight feet beneath sea level and about sixty feet from the edge of the bluff. Mining operations were started and it is near the locality where tradition says a Spanish treasure was lost. Samples of asphalt, hasemanite ore and the piece of schooner mast were presented to the American Museum of Natural History of New York City.

The Material at St. George, Ga.—The chemical nature of the material near St. George is the same as that at Haseman, but the St. George deposit is softer and has more clay and humic acid in it, and the sand is finer.

This deposit is about forty miles from the present sea coast, but the exposures of the Okefenokee, Satilla and Charlton formations prove that the region has recently been covered by shallow salt water and even though it is on the edge of a high sand ridge, portion of Trail ridge, the deposit is almost surrounded with small fresh water swamps and the soil supports the same growth of plants as at Haseman.

The topography of this region indicates that the St. Marys river robbed the Swanee river of that portion of the former which now lies between its big bend where it cuts across Trail ridge and the Okefenokee swamp. This taken in connection with the peculiar location and elevation of Trail ridge explains the origin of the Okefenokee swamp.

The many small swamps adjacent to Okefenokee also supported extensive growths of bog plants, and the sandy ridges were covered with black jack and dwarf oaks, spruce and stunted pines and saw palmettoes. The peculiar decay of these plants formed large quantities of dilute humic acids which either entered the adjacant streams or percolated down through the sand to the underground water level which fluctuates a great deal from rainy to dry seasons. In certain locations large quantities of humic acids were precipitated and cemented the sand in such a way to form hard-pans. Iron salts, acid salts, sea water and possibly electro-chemical processes associated with the black sand minerals were the chief agents of this precipitation.

As these hard-pans were more or less impervious to water, they frequently changed the levels of the underground water which in turn often formed a second and sometimes a third hard-pan in the same locality.

PROBABLE CHEMICAL CHANGES OF HUMIC ACID

The decay of plants is entirely different in muddy and coarse sandy swamps. In the latter swamps, such as Okefenokee, decaying plants form humic acids and humic acids incorporate nitrogen and form azo-humic acids which in turn take up some silica and form azo-silico-humic acids. Some of these acids form dopplerite, which forms both cassel or van dyke brown and asphalt under special conditions. It is interesting to note that where these reactions take place, the swamps are rarely unhealthy.

The presence of hydrogen sulphide, methane and other gases in deposits of fossil humic acids suggest that when asphalt has been synthesized from humic acids that it might combine under special conditions and form crude petroleum The chemical formula of dopplerite also suggests that it might be changed into anthracite coal by the loss of most of its oxygen and a little of its hydrogen and nitrogen. The fact that it is soluble in water would allow it to be deposited in great thicknesses.

The following table of average analysis illustrates the chemical relationship of coal, lignite, asphalt and van dyke brown to humic acid.

		Percent			Percent
Humic acid	C	60.00	Dopplerite	C	56.60
	H	4.00	(Solution in	H	5.48
	O	36.00	water)	O+N	38.06
Vandyke Brown	C	53.00	Lignite	C	75.00
(Solution in	H	7.00		H	5.50
water)	N	3.00		N	1.38
	O	37.00		O	8.00
Asphalt	C	82.33	Bituminous Coal	C	82.20
	H	10.69		H	10.69
	N	.81		N	.81
	O	6.18		O	6.16
Grahamite	C	83.00	Anthracite Coal	C	94.00
(fossil asphalt)	H	2.00		H	2.30
	N	.80		N	1.45
	O	14.00		O	2.25

The humic acid origin of asphalt also gives a logical explanation of why salt water is usually associated with deposits of crude oil. Salt water precipitates a solution of humic acid such as sap brown, etc. Hence the dark coloring matter in certain swamp water is precipitated in the sand, mud or lime along the coast. It tends to form impervious layers until the precipitated humic acids are changed into crude petroleum and hence some salt water is cut off by the impervious layers of sand, mud or lime which later turns into the oil bearing sand.

It is also suggested that the bases of crude oil did not come directly from coal but from the humic acids of coal and lignite producing swamps near the sea or salt water, or else the humic acid flowed to or percolated to salt water. If this be true, then future oil geology and prospecting can be carried on in a slightly different manner. For example, there should be large deposits of crude oil in the Tertiary deposits of the East Andean Sea of the upper Amazon Valley between Obidos and the Andes Mountains because this region had immense swamps and salt water before the Amazon became a reversed river (about or after the Miocene). In fact, the crude oil found near the mouth of the Orinoco river, near Tampico and at least part of Tertiary oil of Louisiana and Texas could easily have been formed from fresh water humic acids which were deposited in sediments of coastal swamps under conditions like Okefenokee swamp near the sea or a large black water river like Rio Negro at Manaos, Brazil, flowing into a shallow sea.

CONCLUSIONS

1. Asphalt is formed in hard-pans directly from the geochemical transformation of plants.

2. Sap brown and van dyke brown can be manufactured from certain hard-pans which are also due to geochemical transformation of plants.

3. Asphalt and van dyke brown found in the hard-pan, hasemanite, are transformed products of humic acids.

OIL AND GAS DEVELOPMENT IN WEST VIRGINIA FOR THE YEAR 1920

DAVID B. REGER

Oil and gas developments of the past twelve months in West Virginia have been mainly of a routine character. Outstanding features for the year may be summarized as follows: (1) The large number of good oil producers found in the Maxton sand in the Laurel Fork of Tanner Creek pool, western Gilmer county, (2) A further extension of the Cabin creek pool of Kanawha county westward into Sherman district, Boone county, (3) The discovery of a Berea sand well in Mason county, northeast of Point Pleasant in the so-called "flat structure" region, (4) The further exploitation of the Heck pool, northwestern Roane county, (5) The further extension and development of the Cottontown (Maxton sand) pool east of Burton, Wetzel county, (6) The discovery of oil in the Benson sand, western Barbour county, (7) The search for Speechley sand gas in the northern counties, resulting in almost total failure, (8) Routine activities in old fields, and (9) Prospecting in new territory.

LAUREL FORK OF TANNER CREEK POOL

The Laurel Fork of Tanner Creek pool, situated, as indicated in western Gilmer county near the village of Tanner, has been exploited intensively by several companies which have comparatively small holdings. The wells, which produce from the Maxton sand, range in size from 25 to 200 barrels and only a few dry holes have been found within the limits of the pool as now recognized and declared fully defined. The extent of this pool is not large, embracing probably not more than 1,200 to 1,500 acres, being situated on a well defined structural terrace which interrupts the continuity of the Robinson syncline. The Maxton sand is recognized as a consistent producer in small

David B. Reger, Morgantown, W. Va. Published by permission of the West Virginia Geological Survey.

isolated pools, which often have little relation to any definite structure, the controlling element apparently being the lenticular character of the sand, which recurs from place to place, with the necessary thickness and porosity to produce oil. The Laurel Fork pool is apparently due to the combined effect of favorable structure and favorable lithology, making it the leading field of its class in the state.

THE CABIN CREEK POOL EXTENSION

The Cabin Creek pool, as predicted by the writer last year,[1] has been extended two or three miles westward on the waters of Big Coal river, Sherman district, Boone county, where Berea sand wells of 100 to 300 barrels capacity are being secured. The wells are located on the north side of the Handley syncline, the axis of which, as plotted on the Berea sand, is shifted two to four miles south of the basin indicated by surface coals, its different position being due to southeastward expansion of the Pottsville, Mauch Chunk and Greenbrier series. The ultimate westward extension of this pool is conjectural, but it seems doubtful whether it will pass beyond Little Coal river, as the sand becomes extremely hard and close beyond that stream. If it should extend farther its probable position will be somewhat higher on the structure where oil may have been trapped by the impervious sand along the lower contours near the basin.

MASON COUNTY WELL

As forecasted by the writer last year[2] prospecting has proved successful in the "flat structure" near the Appalachian geosyncline in Mason county, the discovery well (R. J. Patterson No. 1 of the Prospect Oil & Gas company) being located eight miles northeast of Point Pleasant and fifteen miles northwestward from the Parkersburg syncline by which title the Appalachain basin is locally known. At this well the Berea sand was found at a depth of 1811 feet and produced eight barrels of oil daily with a small amount of salt water. Inasmuch as wells of this moderate depth and capacity in a long-

[1]Bull. Am. Assoc. Pet. Geol., Vol. 4, No. 1, p. 31; 1920.
[2]Ibid., p. 31.

lived sand can be operated quite profitably it would appear that a pool of considerable extent may result. The presence of a small amount of salt water is not considered deleterious, since it tends to act as an emulsion in bringing out the oil and preventing paraffin from clogging the pores of the sand. The well is located in an extremely shallow basin approximately parallel to the Parkersburg syncline, the contours indicating a possible pool eight or ten miles long and a mile or more in width.

THE HECK POOL

The Heck pool, located in the northwestern corner of Reedy district, Roane county, just east of Liverpool, on a gently pitching structural slope between the Flat Fork anticline and Parkersburg syncline, where a single well had been completed one year ago, now has ten or twelve good wells in the Berea sand, some of which have an initial capacity of 100 barrels. Active drilling is still in progress and the limits of the pool have not yet been defined.

THE COTTONTOWN POOL

The Cottontown pool of Wetzel county, lying just east of the village of that name and a short distance from Burton has been drilled intensively during the last year, production being in the Maxton sand, the wells ranging from 10 to 30 barrels and holding up remarkably well. The producing belt is just west of the Robinson syncline, as plotted on the Pittsburgh coal, but as sub-surface contours on the deep sands of the Devonian differ materially from those on the Pittsburgh coal, the structural relationship of the Maxton sand, which occupies an intermediate position, is not definitely known, no contours having been plotted for it.

BENSON SAND OIL IN BARBOUR COUNTY

A well (Sigley No. 1 of the Hope Natural Gas Company) has recently been completed on the waters of Elk creek, two miles west of Elk City, western Barbour county, that is credited with a production of four barrels daily in the Benson (possibly same as Bradford ? or Kane ?) sand, at a depth of 4,150 feet, and approximately 4350 feet below the Pittsburgh

coal. This well is situated two miles east of the Ligonier syncline, along which a half dozen Benson sand gas wells have been drilled. Although its capacity is insignificant and present surrounding development indicates little hope of a commercial pool, the fact that only a few wells in the world have found oil at depths below 4,000 feet lends much interest to the discovery.

THE SEARCH FOR SPEECHLEY SAND GAS

The attempt to find Speechley sand gas in the northern part of the state has resulted in almost total failure. Three or more wells have been drilled to this horizon in western Monongalia county, one in southwestern Wetzel and three or more in Harrison. So far as known all of these wells were failures except one in the latter county which was of commercial size. Evidence at hand seems to indicate that the Speechley sand throughout the main gas fields of the northwestern portion of the state is too closed grained or lenticular to be an extensive gas reservoir, and it would appear that its exploitation would be more hopeful farther east toward the Alleghanies where littoral conditions and courser sand might be expected. The spectacular McKeesport field of Pennsylvania is located much nearer to the mountains than most of the deep tests of West Virginia, the above outlined conditions apparently prevailing. In southeastern Braxton county (West Virginia) a well was once drilled near Baker Run Station, the owners of which claimed to find gas of two million feet capacity from a sand that appears to be the Speechley, its location being apparently near enough to the mountains to secure littoral conditions.

ROUTINE ACTIVITIES IN OLD FIELDS

Intensive development of both oil and gas territory in the old, defined fields of the state has resulted in many small wells and a few good producers, probably two thousand wells having been drilled. A completion worthy of note was a well (John W. Price No. 2 of J. H. McDermott Oil & Gas Company) drilled to the Sixth (Bayard) sand in Clay district, northern Monongalia county, which produced 200 barrels daily. The Bayard sand lies below the main producing horizons of the

state and heretofore has yielded nothing better than an occasional gas or light oil well, although many holes have been drilled through it. Perhaps Ritchie has had more completions during the year than any other county.

PROSPECTING IN NEW TERRITORY

Prospecting for oil and gas in new territory southeast of the main fields has resulted largely in failure. One or two additional gas wells have been found in Raleigh county. A deep hole in Wyoming county has produced nothing to date and another in the same county had one half million feet of gas in the Maxton sand but has not yet been completed to the contemplated lower depth. A well in Kanawha county south of Marmet found oil in the Big lime (Greenbrier) but surrounding development does not indicate a pool. In Braxton county the Burnsville gas field has been extended several miles southeastward and the surrounding region possibly offers more hope of new gas than any other in the state.

GEOLOGICAL NOTES

ZACAMIXTLE POOL MEXICO

The most interesting Mexican development of the past year has been the discovery of the new Zacamixtle pool. This new pool lies on the buried ridge or fold of Tamasopo limestone which extends from Dos Bocas to Cerro Azul and perhaps to Potrero del Llano and Alamo. Zacamixtle is the fifth major field to be discovered on it, or seventh if Potrero and Alamo are included.

The ridge of limestone (sub-surface) undoubtedly shows folding but it has also some resemblance to a buried ridge such as the granite ridge in Kansas.

Los Naranjos, one of the fields on this ridge, yielded a production of approximately 95,000,000 barrels of oil in 1920—something of a record for the production of any field for a single year.

E. DEGOLYER.

IMPORTANT OILFIELDS IN NORTHERN CANADA

The flowing well in the north of Canada which has been drilled by the Imperial Oil Company may lead to developments of far-reaching importance to the American oil industry. A resume of the known facts should be of interest to the Association of Petroleum Geologists.

Position of the Well—The well is situated on the right bank of the Mackenzie river, in the North-West Territory, about 45 miles north of Fort Norman, in Latitude 65½°. It is the first well to be drilled in this great province, which occupies more than half of Canada. It is, also, the most northern oil well in the world, and is many hundreds of miles distant from any other well.

Transportation to the new oil field, at present, is difficult, for there are no railroads in the North-West Territory. The two nearest railroad terminals are in Northern Alberta, at Peace river, and at Fort McMurray on the Athabasca river. The oil-well is about 1000 miles beyond these terminals. From the end of steel, the drilling machinery was conveyed northwards down the rivers in 1919. Part went by way of the Athabasca and part went down the Peace. They continued down the Slave river, across the Great Slave Lake, and then down the Mackenzie river, to the location.

Result of the Test—The drillers remained in the North through the winter of 1919-20 and the hole was drilled in 1920. According to the statements which have been given out, oil sands yielding a few barrels a day were met with at frequent intervals all the way down until at a depth of about 800 feet the oil suddenly spouted up from the 6 inch casing to a height of 15 feet above the top of the derrick. It is expected that the

production will exceed 1000 barrels a day. In the words of Mr. C. O. Stillman, President of the Imperial Oil Company,—

> On the 25th of August, at a depth of 783 feet, oil was encountered which flowed out of the 6 inch pipe for thirty minutes, when the well was capped and shut in. Any estimate as to the amount of oil this well would produce is only a guess, as there was no tankage available, and an accurate test could not be made.

Discovery of the Field—Oil Seepages in the Mackenzie basin were observed by the early explorers and were noticed in the Canadian Geological Survey Reports by R. G. McConnell in 1891.

But it was not until 1914 that this great region was systematically explored for oil by Dr. T. O. Bosworth, of London, with a corps of geologists and surveyors, acting for a Canadian syndicate . The expedition was reported to have determined a number of promising oil fields. They staked claims on the Mackenzie river and also on the shores of the Great Slave Lake. The test well, which has now proved so successful, is on the claim filed by Dr. Bosworth in his own name, and was located by him 6 years ago.

In 1914, the transportation difficulties were greater than they are today, for the railroads had not then reached northward to the navigable rivers. No doubt the war also delayed the exploitation. But last year, the claims were acquired by the Imperial Oil Company, and the drilling of the farthest north well was promptly undertaken.

A second well into the North-West Territory, also, is being drilled by the Imperial Oil Company, on the claims at Windy Point, on the north shore of this Great Slave Lake.

It is expected that next year will see considerable activity in both of these fields.

Geology and Prospects—The oil well at Fort Norman is situated on Devonian rocks. The Devonian formation here occupies a very large area, extending all along the Mackenzie river.

No detailed account of the geology has been published, but the following are (reported) statements made by Dr. Bosworth in 1915.

> The Devonian was a great petroliferous formation: it's various subdivisions, or, at any rate, a large part of them, had been worked out by him during the past summer . . . in some parts there were systems of folding and mountain-building anticlines

> The source of the oil in the Devonian formation was a thick black shale, several hundred feet thick, and much black bituminous limestone. From the shales, oil could be distilled, and it was obvious that the oil had been derived from them, and passed into overlying porous rocks, sandstones and dolomites, in the Devonian formation. The black shales covered a wide extent of an enormou area, and in some places they were actually undergoing combustion at the present time. In several places oil was seeping out from the Devonian rocks into the water for distances of several miles. In other place there were large deposits of asphaltum. Yet again there were numerous pools of oil which could be baled out with buckets. (Journal of The Institution of Petroleum Technologists, Mareh 1915, page 142.)

In an address to the Edmonton Industrial Association in 1915, Dr. Bosworth was reported to have said,

> far away in the regions of the Great Slave Lake and the Mackenzie river, we found promising oil fields—not one field, but a number of fields. In these, there are all the structures and indications proper to great oil fields. The oil originates in a thick series of bituminous shales. In places these black rock are burning at their outcrop, so that there are high cliffs of them, burnt to a bright brick-red color. Oil has been generated from this

series, and is now stored up in various over-lying porous formations of Devonian Age. Thus there are in some districts, sandstone saturated with oil, and in other districts porous dolomites completely soaked with oil. The oil differs in the different fields, as also do the containing rocks.

There are places where one may walk for miles along the water edge and all the way, see oil seeping out freely into the water, or even flowing out into the water. There are large spreads of pure pitch and there are many pools of oil from which the oil can be drawn out in a pail.

Value of the Oil—The oil from the Fort Norman well is of light gravity, with parafin base, and contains a high percentage of gasoline; but at such great distance from markets, it can be of little use until better transportation and costly pipelines are provided.

In his announcement to the Press, Mr. Stillman states:—

We consider this an important strike, and scientifically of much value. From a commercial point of view, however, it is not of immediate value, as it will probably be years before it can be made available in quantities for the use of the Canadian market, on account of it's remoteness from any refinery outlet. . . . It would be necessary to demonstrate by actual drilling and production that there was a sufficient quantity of oil to justify the laying of a pipeline, which, in itself, would probably cost fifty million dollars. There is another important element which mitigates very much against the commercializing of any oil found in this territory: that is, the extreme cold, which makes the rivers navigable for only three or four months of the year. The extreme cold in this Arctic region would also mitigate very largely against the handling of this oil in the winter time.

With these facts in mind, it must be realized that to render the oil from this Arctic region commercially accessible would prove very costly, and the problem will require great study before any means can be devised of getting the oil out to compete with crudes from other centres of production.

OIL AND GAS IN MONROE COUNTY, ILLINOIS

The third well on the Waterloo-Columbia dome, Ellis and Sutherland's Robert Friedrick No. 1, SE.¼, SW.¼ sec. 35, T. 2 S., R. 10 W., is very encouraging. This well found the "Trenton" at about 370 feet and the pay from 391 to 427½ feet. The well was not shot. The "sand" is a porous crystalline lime (Kimmswick) and apparently not dolomitic. The well was pumped first on January 27 and 28, 1921, and made approximately 250 barrels of oil the first day. pumping on the beam from one string of 2-inch tubing. Lack of tankage has to date prevented a thorough knowledge of the well's capacity. At present it is being pumped by a small gasoline engine, from two strings of 2-inch tubing. The nature of this temporary outfit may be insufficient to properly gage the well. The Ohio Oil Company's Gaertner Nos 1 and 2, have not been pumped as yet but are now equipped to pump. These wells were shot and can not be estimated accurately at present; they are apparently considerably smaller than the Friedricks No. 1.

The first sample of oil taken by the State Survey showed the oil to be rather exceptional at least for Illinois oil. The Beaume gravity was 30.1° at 60° F. but about 5 per cent gas was evolved from the sample. With less gas the gravity of this oil will probably be well below 30°. The coke residue was exceptionally high—about 20 per cent—but the oil recovered was apparently much lighter than would be expected from a crude of this gravity and the products at the temperatures at which they were

obtained seemed unusually light. More tests are under way, and it is possible that the quality of the distillates may considerably offset the disadvantage of the high coke residue.

The chief significance of the wells to date is that where suitable local structure exists in this area it is reasonable to expect commercial production in the "Trenton" horizon. The shallow depth necessary to test the sand makes driling inexpensive and the possibility of finding wells as large as Ellis and Sutherland's Friedricks No. 1 may encourage wildcatting. But as other major structures exist in this general area, it is hoped that geological work may find other local structures equivalent commercially to the Waterloo dome so as to confine the drilling to the most likely localities.

The comparatively high relief of this area allows only very accentuated local irregularities to be seen without detailed leveling. This area was first worked some years ago by Dr. Stuart Weller of the Survey and his maps brought out the Waterloo-Columbia dome without detailed leveling. Dr. Weller's work also shows the continuation of this anticline northward to the Mississippi river bluffs near Sugar Loaf School. Another anticline outcropping at Salt Lick Point above Valmeyer brings the "Trenton" to the surface but the trend of this fold is southeastward in which direction the cover gradually thickens over the "Trenton", just as it does eastward toward the Waterloo-Columbia fold. In both these general areas it is possible that local structures exist—L. A. MYLIUS, Illinois Geological Survey.

FLOWING WELLS IN PENNSYLVANIA

Those interested in the maximum utilization of pressure for extraction will find an interesting pool on Little Pine creek near Undercliff, Allegheny county, Pa. These wells yield only a few barrels a day but flow it. The practice apparently is to open the well merely long enough for the flow and not to take any gas for gasoline or fuel purposes. This practice is interesting in view of Miles W. Quick's contentions as to the value of intermittent relief of pressure.

ROSWELL H. JOHNSON.

THE PRESENT EXCITEMENT AT FORT STOCKTON, TEXAS

During the past year a number of shallow wells have obtained small quantities of heavy oil about 14 miles northeast of Fort Stockton, Pecos county, in Southwest Texas.

Early in January the eighth well in this group was completed at a depth of 96 feet with an initial production estimated as equivalent to several thousand barrels daily. The news of this completion created considerable excitement throughout Texas in spite of the fact, not so generally given out, that the well ceased to flow after a few hours.

The wells were all drilled in a circular depression about 100 feet in diameter and 2 feet deep. Such depressions are rather common phenomena over the arid plains of Pecos and Reeves counties. Another group of shallow oil wells like those at Fort Stockton is located in a precisely similar depression some 20 miles northwest of the town of Toyah in Reeves county. The depressions are usually marked by the presence of gypsum, sulphur, sulphur water, and seeps of hydrogen sulphide gas. At the site of the Fort Stockton wells there is alleged to have been an oil seep also, even prior to the drilling of any well.

The general geology of the surrounding region is well known. The surface is Quaternary outwash, irregularly coarse and fine fragmental material, which attains local thicknesses of hundreds of feet. Beneath the Quaternary are thin remnants of Lower Cretaceous at places over a general Permian floor. The Permian contains the following formations in descending order: Red Beds (clays and sands; maximum thickness about 1200 feet); Rustler Dolomite (200 feet); Castile Gypsum (gypsum, limestone and sulphur, 300 feet); and beneath an unconformity, the Delaware Mountain Limestone consisting of probably 2,500' of limestone distinctly petroliferous and sandy toward the base.

The Delaware Limestone is presumed to be the source of the oil in the wells of this region. The oil in the shallow wells is believed to be upward migration from the underlying source, trapped in unconsolidated Quaternary sands. Deep wells also have encountered petroleum in the Delaware at various places in Reeves and Pecos Counties, but nowhere in paying quantities. An old well was drilled years ago at the site of the present Fort Stockton excitement, to a depth of 1200 feet and obtained a show of oil in the upper Delaware. As a matter of fact, it is not unlikely that seepage upward from the bottom of this hole during the past several years may account for the accumulations in the shallow sands at this place, although there may actually have been a natural seep of oil there as is claimed.

The Delaware Limestone is a possible source adequate for commercial accumulations of petroleum and it will be surprising if at some place in southwest Texas such commercial supplies are not obtained eventually. The difficulty is to find the proper structural conditions for accumulation. The Quaternary wash largely obscures the surface exposures, and the unconformity at the top of the Delaware further complicates matters. The considerable proportion of limestone and other frangible beds in the column tend toward faulting rather than unbroken folds. In spite of these difficulties however, favorable structure undoubtedly will be found eventually, and commercial production may well ensue. There is, as a matter of fact considerable evidence of favorable structure in the vicinity of Fort Stockton and no well there has gone deep enough to reach the base of the Delaware, where a proper reservoir might be anticipated.

WALLACE E. PRATT.

THE RECENT DISCOVERY AT EL DORADO, ARKANSAS

On January 10, 1921 Mitchell & Busey succeeded in completing Armstrong No. 1, a well started early in the previous year by Maddox & Hinton about 2 miles west of El Dorado, Arkansas. The well came in as a gas well spraying oil in volumes variously estimated from 15 to 35 million cubic feet and 3000 to 10,000 barrels of fluid, respectively. The flow contained considerable water, but this may be presumed to come from up the hole since the 6-inch casing was set about 2000' whereas the total depth is 2223, and the top of the sand at 2180 feet. By the first of February the well was spraying 1000 to 1500 barrels of clean oil, choked down. The oil is brown in color, 36° Baume gravity and contains large proportion of gasoline. Six other wells all making large volumes of gas and some oil, have been brought in over an area about two miles in length southeast of Armstrong No. 1.

In the minds of the industry in general this completion will mark the discovery of whatever oil and gas field may develop in the El Dorado territory, although the actual discovery was made a year previously by the Constantine Refining Company which completed Hill No. 1, a 40,000,000 gas well spraying oil, on April 22, 1920, about two miles south of Armstrong No. 1. Moreover—and the fact is of particular interest to the Association—Constantine's location was a purely geological venture, Mr. J. J. Victor his geologist not only made the location but supervised the drilling of the discovery well.

In the face of this fact one hears a great deal of contention that the Armstrong well was a surprise to geologists; that no geologist was expecting anything of South Arkansas. As a matter of fact not only was the discovery well a geological location, but a number of the larger companies which follow geology were holding acreage in the area and the United State Geological Survey issued a Press Bulletin during the summer of 1920 rather urgently calling attention to the petroleum possibilities of this very area. The examination for this bulletin was made by Mr. K. C. Heald.

As to its petroleum and gas, South Arkansas is related to North Louisiana. Not only is the oil of similar character and the production methods and problems alike, but the producing horizons appear to be identical. The El Dorado production appears to come from about the position of the Nacatoch sand in the Upper Cretaceous. Although a recent discussion in the non-technical press places it in the Woodbine Sand because of the approximate equivalence of depths at El Dorado and at some of the producing fields on the Sabine Uplift where the Woodbine is the reservoir. Another current and slightly more tenable suggestion is that it is the Blossom sand horizon. But the most logical interpretation of the well log in connection with the surface exposures makes the producing horizon probably Nacatoch, or, at any rate, the same as the upper producing horizon at Homer which is conveniently referred to the Nacatoch.

The geologic structure at El Dorado is not yet portrayed in detail. Absolute reliance is not to be placed on the local attitudes of the surface beds although careful areal delimitation appears to afford some clue to the structure.

The geologic structure at El Dorado is not yet portrayed in detail. All completions to date in the vicinity of the discovery well are structurally high, and are approximately equal in elevation. There are structurally low completions at some distance from the production in several directions. The general structure at El Dorado is therefore favorable.

The showing distribution and sand elevations of the present wells lead to the belief that large commercial production will be obtained and the discovery is considered to be one of the most important in America for the year 1920.

WALLACE E. PRATT.

A NOTE ON SUPPOSED EVIDENCE OF THE VOLCANIC ORIGIN OF GULF COAST SALT DOMES

A half dozen specimens of rock of suspected igneous origin have come to the writer during the past two years from wells on Gulf Coast Salt domes. These samples were submitted in nearly every case with the idea that they proved the igneous or volcanic origin of salt domes. In reality, probably out of some two score actual students of Gulf Coast salt dome phenomena at the present time not more than three or four, or say, one in ten, will question the validity in its essential features of the theory of intrusion of the salt plug by plastic flow upward from a deeply buried, highly compressed parent bed of salt, yet the question of the origin of salt domes returns to plague all of us more or less frequently, and one of the most persistent offenders is the volcanic theory.

De Golyer[1] in an excellent review of the theories of origin of salt domes devotes thorough discussion to the theory of related vulcanicity and while he finally rejects that theory in favor of intrusion of the salt from below by flowage, he is unable to explain certain apparent evidence of vulcanicity observed and cited by Rogers,[2] namely "the discovery during the past summer of volcanic ash in the sediments around one or two of the domes; of a rock resembling a porphyry in a well at Damon Mound; and of an undoubted igneous plug about 50 miles north of the salt-dome belt."

Powers[3] is also puzzled by Rogers', mention of "one small igneous plug of late Tertiary or Quaternary age" which "has recently been discovered between the Coastal domes and those in northern Texas,"[4] and suggests

[1]De Golyer, E., The Theory of Volcanic Origin of Salt Dames, Trans. Am. Ins. Min. & Met. Eng'rs. Colorado Meeting, September, 1918.

[2]Rogers, G., Sherberne, Discussion of Matteson's paper, Principles and Problems of Oil Prospecting in Gulf Coast Country, Bull. 136. A. I. M. & M. E., 1918, 824.

[3]Powers, S., The Butler Salt Dome; Am. Jour. Sci., 49 (1920) 140.

[4]Rogers, G. S., Intrusive Origin of Gulf Coast Salt Domes, Econ. Geol., 13 (1918) 458.

that Rogers probably had in mind a reported occurrence of "porcelainite" in Grimes county.

If the facts concerning the reported porphyrs and other igneous rocks from salt dome wells and the alleged igneous plug in the country adjacent to the salt domes, could be definitely ascertained the theory of volcanic origin for Gulf Coast salt domes might be analyzed with somewhat more precision. This little paper aspires to record something of the facts in question.

Preliminary inquiry makes it clear that Rogers' porphyry from a well at Damon Mound was very similar to the "igneous rocks" that have come to the writer from Davis Hill, Pierce Junction, Damon Mound, Strattor, Ridge and other salt domes, and that his "one small igneous plug" is, as Powers suspected, the Grimes county porcelanite, (or possibly the similar and adjacent Brazos county occurrence described below).

The Grimes county "plug" is about 60 miles north of Houston. It was examined recently by the writer in company with John R. Suman and W. K. Kelley. The locality is the Benjamin Smith Survey near the center of the county, about ten miles north of the town Anderson. It is spoken of locally as the "Red Hills" and is characterized by two reddish knobs or low hills protruding about 10' above the floor of a small stream valley. Upon examination these knobs prove to be formed of bedded clays and sands containing a considerable proportion of volcanic ash, of probable Jackson age. They are indurated and reddened as though by heat and locally are fused completely to a gray to black glass. A pit has been sunk on one of these mounds to a depth of 15 feet or so. In the lower part of the pit lignitic and ash-like material were penetrated. The overlying beds show brecciation and local displacement as though by subsidence. Lignite is abundant in the Jackson beds surrounding this locality.

An even better example of this identical phenomenon is to be found near the bridge on Boggy Creek at Clay's Farm in Brazos county, just east of Grimes county. A lignite bed, overlain by the fused and baked clayey and sandy volcanic ash, the lignite partly burned, and the overlying beds subsided, displaced, and broken are clearly displayed in the west wall of Boggy Creek just below the bridge. Thin sections of the fused material from this locality reveal a blebby, cloudy glass with small angular to rounded inclusions of quartz. Megascopically the rock is not unlike rhyolite in appearance.

The Grimes and Brazos county "plugs" are therefore, indurated, baked, and fused beds of volcanic ash which overlie lignite beds and were heated by the burning of the lignite in place. No possible question of the correctness of this explanation occurred to any of the three observers mentioned above. So much, then, for the "igneous plug" which has served to lend support in the past to the theory of volcanic origin for Gulf Coast salt domes.

The apparently igneous rocks that are obtained from wells on salt domes are all alike glassy, felsitic, and pyroclastic material, gray, green or black in color and often scoriaceous in texture.

A sample taken from a core barrel in Texas Exploration Company's Ritter No. 1 at Pierce Junction, Harris county, depth 2386, was obtained through Mr. J H. Meeks scout for the Sun Company at Dayton, Texas. This sample consisted of a small angular fragment of greenish to dark colored glassy felsite exhibiting flow structure. Microscopic grains of quartz, angular to rounded and with an altered border zone, in a matrix of dark colored, cloudy glass were revealed by thin section.

A sample from Jacksonville, Florida Oil Company's test east of Goose Creek, Harris county, taken from core barrel at 2980' is similar microscopically to the material just described but contains also metallic iron. Megascopically it is gray, green, and black scoria with angular inclusions of gray, felsitic material like indurated shale, and considerable glassy felsite. The specimen is four inches in diameter (full diameter of core barrel) and about three inches thick.

A small specimen with freshly conchoidal surfaces secured by core barrel from Humble Oil & Refining Company's Brock No. 2 at Stratton Ridge, Brazoria county, depth 2755 feet, is a green to grayish black glassy felsite described petrographically as:

50 per cent cloudy glass

40 per cent semi-angular quartz grains .005 to .01 inches indiameter.

10 per cent metallic iron.

With this specimen in the core barrel was a larger volume of gray, sandy clay.

Rocks identical with those described in the foregoing paragraphs have also been obtained from core barrel samples taken at Davis Hill and at Damon Mound, but further detailed description is beside the point for the various samples are all of the same general character.

Such then is the nature of the suspected igneous rocks from Gulf Coast salt dome wells. Other geologists have obtained samples from some of the wells listed, notably from the Pierce Junction well. A number of geologists, also, have examined the writer's specimens. None of these men escaped an immediate impression of the apparent igneous character of the rocks.

Yet the samples are by no means of igneous origin. They represent simply clays which are indurated and fused by the best of pressure and friction in the coring process. Even the drillers who take the cores usually do not recognize this fact, for the fusion has cooled before it reaches the surface and either no longer adheres to the core barrel or is broken from the metal before the driller succeeds in cutting off the sealed, lower end of the barrel in extricating it. The degree of heat created by the final "pinching off" of a core sample in an ordinary rotary hole is not generally appreciated. It is sufficient to fuse the center of a four-inch

clay core to a pasty scoriaceous mass which twists and swells and flows in the barrel, and to vitrify the perimeter perfectly. A quartz, sandstone or limestone will not be so fused; quartz grains in the fused clays are only affected on their surfaces. As a matter of fact, the clays and sandy clays most frequently fused contain a large proportion of volcanic ash, the low melting point of which probably makes the clay readily fusible. The metallic iron noted in several of the "igneous" specimens comes, of course, from the core barrel.

Thus are the igneous rocks in Gulf Coast salt dome wells to be explained in at least a half dozen cases which the writer has investigated. It is certain that similar "burned cores" have perplexed others and have tended to keep alive the belief that Gulf Coast salt domes are related in origin to volcanic action, and conversely it is likewise probably true that no rock of igneous character other than fused core-barrel samples has been obtained from Gulf Coast wells.

WALLACE E. PRATT.

GEOLOGY AND OIL AND GAS POSSIBILITIES IN THE VICINITY OF WATERLOO, MONROE COUNTY, ILLINOIS

A circular issued in April, 1920, by the Illinois Geological Survey calls attention to a promising area southeast of St. Louis. Earlier work by members of the State Geological Survey in the vicinity of Waterloo in Monroe county showed the presence of geological conditions which were favorable to accumulation of oil and gas. A sketch map shows the formation involved in a fold between Waterloo and Columbia, the location of the outcrops, and gives a generalized section of the geologic column.

Mention is made of a fault which borders this fold on the west, and suggestions are offered as to the most favorable places to locate the first test holes.

Subsequent findings have justified the Survey's recommendations, for one well recently completed here indicates an initial daily production in excess of 200 barrels, and there seems little doubt but what a small pool may be opened up in this area.

OIL AND GAS PROSPECTING IN PARTS OF COLES, EDGAR, AND DOUGLAS COUNTIES, ILLINOIS

A bulletin issued by the Illinois Geology Survey in May, 1920, reviews the results of some of the diamond drilling in these counties. A porous dolomite (Upper Hamilton?), oil bearing in at least one hole was found about 900 feet in Sec. 17, T. 14 N., R. 14 W., and this well, with others in that area, confirms the existence of the newly discovered fold which extends north and south near Oakland.

OIL AND GAS PROSPECTING IN PARTS OF CLARK, COLES, EDGAR, DOUGLAS, AND CHAMPAIGN COUNTIES, ILLINOIS

An Illinois Geological Survey circular, July 1920, discusses in more detail than previously the Trenton studies. The area considered is taken up under two headings: (1) south of Westfield, (2) north of Westfield. Although several wells have been drilled here, few go through the Mississippian lime, and few of these logs are detailed enough to be of use. Hence the amount of thickening of the Mississippian to the south, and the exact relation of Trenton structure to overlying beds are not known. Some doming and flattening of the lower beds is suspected, and a map is presented to outline the area where such relations appear to exist. Attention is called to the fact that a test well to the Trenton in Crawford county may be 4,000 feet or more deep.

North of Westfield the fold, which branches to the east of north, seems to flatten east of Oakland. The new oil horizon here previously reported as Upper Hamilton is now considered "Corniferous." Salt water found in one hole at this dolomitic horizon suggests that this zone is well worth further investigation. Two small structures are indicated in the area between Tuscola-Westfield-Oakland. Shallow production in Pennsylvanian sands might be expected here under these conditions.

Attention is called to field work in other parts of the state. A suggestion of thickening of Chester beds in Bond county renders certain areas there of increased importance as oil prospects. A recent well near Ava in Jackson county has reported a good show of oil.

Among the very interesting features connected with the Tulsa meeting of the Association is the exhibition of a peg model of the Garber field, Oklahoma, prepared under the direction of Mr. Jon A. Udden, of the Sinclair Oil and Gas Company. The model covers an area of about 81 square feet. The exhibition is placed in Room 504, Sinclair Building.

Word has been received from the Superintendent of the Bartlesville station of the U. S. Bureau of Mines that the peg model of the Hewitt field, southern Oklahoma, will also be placed on exhibit at the meeting.

EDITORIALS

The addition of several new divisions of the Bulletin will be noted in this issue. These are included in the effort to make the publication of the Association of large service to the membership. It has been the feeling of the officers of the Association that, next to the annual meetings, and in some respects even larger than the meetings the Bulletin may serve to consolidate and to advance the interests of petroleum geologists. It has been found in the course of recent practical experience that it is much easier to issue papers in parts of volumes than in one complete volume, and that this method advances considerably the time when the scientific papers of the Association as a whole can be distributed. For instance, a number of the papers of the 1921 volume are included in this issue and there are already in the hands of the Editor copies of additional papers which can be ready for publication in a very short time, certainly long before some of the delayed contributions are in hand. It is proposed to issue the scientific papers of the Association in four to six parts, to appear from time to time through the year as material is received and accompanying it such additional current news, comments, discussion and notes as the membership desires. The time of appearance of these parts will probably be somewhat irregular, for it is without doubt the desire of the membership to receive the Bulletin at as early a date as the material can be prepared for the printer. Nevertheless, if opportunity is given for the recording of fragments of scientific information as they come to hand during the course of the year, for the submission of papers perhaps at times other than the time of the annual meeting, it will be possible to make and to distribute discussions of problems or topics which come up between the times of the annual meetings. Some of the scientific contributions of members of this Association which should, perhaps, find most fitting place in the columns of the Bulletin, appear in miscellaneous journals which in very many cases do not commonly find their way into the hands of members of the Association who are interested in the contribution. There appear to be very many advantages to the Association which may accrue from a live, going, flexible medium of expression as compared with a mere record of proceedings at a series of annual meetings.

If plans are consummated whereby the geological news and comments from the different regions of the United States and foreign areas in which American petroleum geologists are interested may be compiled and forwarded to the central Editor it will be possible to cover in a much more worthwhile manner than is now done the developments and interests of the entire field. Such news items should consist of first hand, authentic information of geological interest, and while perhaps the information or note is only a fragment, it may be very valuable to record it. Many geologists who find it impossible or undesirable in some cases

to prepare a formal paper on a subject may easily pass on to the Association essential facts or comments which will be of value. It is believed that this less formal interchange may become an increasingly important and valuable benefit of the Association and Bulletin. There is no other publication expressly devoted to the common interests of petroleum geologists and engineers and the Bulletin should be the common medium for the profession and for the advancement of its interests.

It is possible that in the division of Abstracts and Reviews workers in different regions may offer concise summaries and crtiicisms of geologic works and papers dealing with their areas or problems. These will benefit other workers, and while it may not be possible to make an exhaustive review of geological literature of interest to the petroleum geologist, it is probable that most of the publications of special interest to this phase of economic geology can be covered very adequately.

The present Officers have been active in discussions as an executive committee and in consultation with many of the members who are very largely interested in the Association as to methods whereby the interests of the organization may be furthered. The truly surprising growth of the organization, until it is probably the largest association of geologists in the world has presented both opportunities and responsibilities which need the consideration of all who are concerned in the profession. The suggestions and opinions of any of the members regarding phases of Association interests should receive expression.

DISCUSSION

"STRUCTURE"

I have noticed for sometime that the word "structure" is very loosely used by petroleum geologists and it would seem that the Association might do well to appoint a committee representing the various parts of the United States for the purpose of more clearly limiting the proper use of the word.

An instance of this loose usage is contained in the following extract from a report recently written by one of our well known geologists. "The Kern river field in California and the Glenn Pool in Oklahoma are notable examples of accumulations which owe their existence to factors other than geologic structure. In general, both are monoclinal in character."

In the paper mentioned, the author apparently uses the word "structure" meaning "dome" or "anticline," which may be satisfactory in some localities, but in making a general statement such as that above quoted brings out a flat contradiction.

This may appear an unimportant question but one of the boasts of scientists is that they use language accurately. Text books on geology as well as some standard dictionaries define the word as "the character, arrangements shape, attitudes relative positions and development-features of the constituent parts of any rock or mineral or of rock masses or of the great topographical features of the crust." The foregoing definition appears in the Standard Dictionary. It can be seen that the word has a very wide use.

The "Textbook of Geology" by Archibald Geikie Vol. I, 4th Edition, 1903, page 127, carries the following foot-note:

> In the 3rd edition of Jukes' 'Student's Manual of Geology' (1871), p. 93, it was proposed to reserve the term "Structure" for large features, such as characterize rock-blocks, and to use the term "Texture" for the minuter characters, such as can be judged of in hand specimens. M. De Lapparent makes a similar distinction (Traite', p. 619, note). But the practice of using the word structure as it is employed above in the text has recived such a support from the petrographers of Germany, that though I still think it would be preferable to distinguish between **texture** and **structure,** I have adopted what has now the sanction of common usage.

The following is quoted from "Hand Book of Geological Terms and Geology," David Page, 1859, page 340:

> Structure—A term applied in Geology and Mineralogy to denote the form or condition in which the component parts of rock-masses are arranged. Thus we say that certain sandstones have a fissile or laminated structure, that certain basalts have a columnar structure, and that the structure of granite is tabular or cuboidal. **Structure,** in fact, refers to the mode in which a rock is aggregated in the mass; **texture,** on the other hand refers to the manner in which its component particles are internally arranged. Thus, on examining a granite quarry, we find the rocks arranged in large tabular or square-like masses—this is its structure: on breaking one of these blocks we find it hard, close-grained, and crystalline—this is its texture.

The "Hand Book for Field Geologists," by C. W. Hayes, Second Edition 1909, pp 12-123; The schedule for "structure" includes five groups, (1) Monoclines, (2) Folds, (3) Faults, (4) Joints and Fissures, and (5) Metamorphisms.

R. P. McLAUGHLIN.

ABSTRACTS

"LITHOLOGIC SUBSURFACE CORRELATION IN THE 'BEND SERIES' OF NORTH-CENTRAL TEXAS"

By Marcus I. Goldman

Abstract

By means of a graphic log showing the approximate proportion of sand, clay and lime in each sample of well cuttings, in conjunction with glauconitic and phosphatic beds occurring adjacent to stratigraphic breaks, and with the aid of certain distinctive lithologic characters of beds, the "Bend" is delimited and subdivided into units and a correlation of these between two wells 45 miles apart is proposed.

A paper presenting the results of this investigation is to be published by the U. S. Geological Survey as Professional Paper 129-A, which it is expected will be available for distribution in advance of the 1921 meeting of the Association. Anyone can procure a copy by writing to the Director, U. S. Geological Survey, Washington, D. C.

DESCRIPTION OF OIL AND GAS AREAS IN TENNESSEE AND CONDITIONS AFFECTING THE DEVELOPMENT OF NEW AREAS

By Wilbur A. Nelson

Abstract

The largest producing pool in Tennessee is in Scott county, oil being obtained at a depth of 1250 feet from the St. Louis limestone.

Probably the oldest oil pool is the Spurrier-Riverton pool, in Overton, Pickett and Fentress counties. Several wells have come in recently getting oil from the Ordovician, 160 to 275 feet below the Chattanooga "black" shale.

A pool has recently been developed in Sumner and Macon counties, where oil is being obtained 30 to 125 feet below the Chattanooga in wells with an average depth of about 300 feet.

Western Tennessee is being prospected in the vicinity of Reelfoot Lake. Shows of gas have been encountered in the top of the Cretaceous at a depth of about 1700 feet, along the Kentucky-Tennessee line. Drilling is now in progress on a plunging anticline at Huntingdon, Carroll county.

Prospects for additional pools in the Silurian and Ordovician rocks underlying the Highland Rim of Tennessee are very favorable, while deep drilling in the western part of Tennessee into the Cretaceous sands is worthy of considration.

OIL DEVELOPMENT AND PROSPECTS IN TENNESSEE

By L. C. Glenn

Abstract

There is considerable activity in prospecting and drilling in a number of widely separated portions of the State. In several of these, where the rocks are a continuation of those in near-by productive areas in Kentucky, strikes have recently been reported. There is good reason to believe that oil will be found on parts of both the eastern and western Highland Rim and that additional productive areas will be found in the northern part of the Cumberland Plateau.

OIL GEOLOGY OF WARREN COUNTY, KENTUCKY

By Stuart St. Clair

Abstract

In 1920 a new oil field was developed in Kentucky which promises to add largely to the oil production of the State. The field briefly described in this paper is in Warren county and lies just west of Bowling Green.

A gusher sand is found at or near the base of the St. Louis limestone from which initial flows may be as much as 2000 barrels per day, but the wells soon decline. The important sand is in the Silurian rocks from 75 to 130 feet below the base of the Devonian Black Shale and is at depths of 900 to 1300 feet with a thickness of pay sand from 5 to 30 feet. Initial production may be 100 to 200 barrels per day but the average is much less.

OIL SHALES OF KENTUCKY

By Willard R. Jillson

Abstract

The presence of broad outcrop areas of highly bituminous shales in Kentucky has long been recognized During the past year several industrial experimental attempts have been inaugurated to recover oil from these Kentucky shales. Two methods (1) Destructive distillation, and (2) Digestive distillation are being used with success. Stratigraphy of Kentucky oil shales—Devonian, Mississippian, and Pennsylvanian. Summary of analyses, geographic evaluation, possible future commercialization.

THE OUTLOOK FOR OIL AND GAS IN PENNSYLVANIA

By George H. Ashley

Abstract

Present conditions of production in Pennsylvania and the outlook for the future as regards (1) new drilling oil fields, (2) development of new

fields, (3) development of deeper sands and (4) the revival of old fields. (1) will yield much additional oil and hasten depletion of gas, (2) will add little oil but many small gas fields, (3) already well prospected except Oriskany and Medina sands, and (4) much new oil from Bradford and elsewhere.

PETROLIFEROUS FORMATIONS OF THE TAMPICO EMBAYMENT, MEXICO

By Douglas R. Semmes

Abstract

The prolific oil fields of Mexico are situated in northern Vera Cruz between the Panuco and the Tuxpan rivers and within 40 kilometers of the coast.

The Tamasopa limestone, the oldest formation represented, is both highly fossiliferous and extensively saturated with petroleum. The Papagallos shales though less fossiliferous show oil saturation and may have given rise to certain quantities of oil. The Alazan shales likewise show the characteristics of a petroliferous series and have undoubtedly given rise to some oil.

Two hypotheses have been brought forward to explain the source and method of concentration of the oil in the more important Mexican fields. It may have originated in the overlying Papagallos or Alazan shales and migrated downward into its present position in the Tamasopa limestone; or it may have originated in the Tamasopa limestone and become concentrated in the upper part of this formation by the agency of hydrostatic pressure. Evidence bearing on these hypotheses is discussed and the conditions leading to the formation of the large commercial deposits reviewed. It is concluded that at the end of Papagallos time movements took place along the major structural lines and the main anticline along which the southern fields occur became a land mass and was subjected to erosion, and as shale deposition (Alazan) took place along the flanks of this mountain range the Tamasopa was exposed along its crest and large caverns were developed in it, and the uppermost part, which was exposed to the atmosphere, was locally silicified. Finally the encroaching Alazan sea covered the entire area and deposited shales over this eroded surface, so that now the Alazan lies directly over the Tamasopa along the crest while on the flanks the uneroded Papagallos intervenes. Subsequently oil accumulated in the caverns along the axis of the fold and consequently a single well may now drain an enormous pool.

While the Tamasopa is regarded as the only source of commercial production in northern Vera Cruz other formations are known to be slightly petroliferous. The Alazan shales apparently produce an oil quite different in composition than that from the Tamasopa. Seepages and saturation in the shales of Miocene age along the coast indicate that this formation too may have produced small quantities of oil.

THE WEST COLUMBIA SALT DOME AND OIL FIELD

By Donald C. Barton

Abstract

Prospecting started at West Columbia shortly after the discovery of the Spindletop field. The early tests were shallow, but encountered small amounts of oil. The old or Southeast field was not brought in until 1918 and the late spring of 1920 was at the crest of its productivity. In the following July the new or North field was brought in by the Texas Co's. Abram No. 1.

West Columbia lies in the belt of Peistocene coastal prairie bordering the Gulf Coast. The surface mound is a faint one of the central depression type, somewhat obscured by erosion.

West Columbia is a characteristic salt dome with a steep sided, flat topped core of salt, a cap of gypsum, and sedimentary beds dipping quaquerversally away from the salt core. Fossils from one well and a study of the well logs shows that the deepest wells probably reach to the lower part of the Corrigan formation.

The productive sands at West Columbia are found only in the deep lateral sands on the flanks of the dome, probably in the upper part of the Corrigan formation. The oil is of 22° 2 Baume and around 110° F. Although this temperature is above the average for the Gulf Coast fields, the temperature gradient is extremely low. West Columbia is a very productive field. The per acre production of the field is over 125,000 bbls. and for the leases of one company is over 943,500 bbls.

Illustrated by a topographic map, a generalized structure section, graphs of production, of field as a whole and of Sun Co's. and Crown O. & R. Co's. leases, characteristic graphic logs, and composite graphic logs.

A SHORT SKETCH OF THE PALEOGEOGRAPHY AND HISTORICAL GEOLOGY OF THE MID-CONTINENT OIL DISTRICT, AND ITS IMPORTANCE TO THE PETROLEUM GEOLOGIST

By Alex W. McCoy

Abstract

The essential points in the stratigraphy of the Mid-Continent region with maps of outcrops, correlation of formations and a review of previous work are presented in introduction. Paleogeographic maps based on detailed stratigraphic studies are presented and their significance in relation to the occurrence of oil at various horizons considered. The probable orgin of the oil in shale, the most favorable basins from a paleogeographic standpoint, problems of accumulation of oil, production zones in relation to historical geology and the relation of production to structure are considered. The reasons for basin movement, the mechanics of mountain

making and of minor structures are treated with reference to their importance in the production of oil.

DIFFERENTIATION AND STRUCTURE OF THE GLENN FORMATION

By W. L. Goldston, Jr.

Abstract

The Glenn Formation is the only Pennsylvanian exposure in Oklahoma south of the Arbuckle Mountains. This exposure, which covers one hundred and sixty square miles more or less, is located in Carter and Love counties in the vicinity of Ardmore. The sediments of the Glenn are strongly folded and stand practically on edge over the greater part of the area. While in the employ of the Empire Gas and Fuel Company, the writer assisted by C. J. Wohlford, measured a number of sections across these sediments.

The sediments consist of shales, sandstones, limestones and conglomerates, and a total thickness of approximately nineteen thousand (19,000) feet.

In this paper an attempt is made to differentiate and classify this massive formation into its component members, and to correlate these rocks with those of the same age north of the Arbuckle Mountains, and with the Pennsylvanian rocks of Texas.

Considerable detail was made in the study of the structure of the Glenn Formation. Axes of anticlines and synclines were carefully located as most of the work was done with plane table.

A brief description of these folds, together with their relation to other buried Pennsylvanian folds in the region is given.

EXPERIMENTS ON ACCUMULATION OF OIL IN SANDS

By W. H. Emmons

Abstract

It has been observed in many places where oil and gas and water fill openings in porous beds enclosed in impervious ones, that gas rises above the oil and that the oil floats on water. Where the beds are arched to form a dome there is commonly a disc of gas surrounded by a circle of oil which is in turn surrounded by water. In some oil fields this gravitational arrangement is not clearly expressed, because the rocks are not fully saturated, or because the porous portions of the strata are spotted with impervious areas. The gravitational theory, because of the difficulties it has met in some fields, has appeared inadequate to many investigators, and elaborations and supporting theories have been proposed.

If, in a tube bent to represent an anticline, oil and water are charged with sand, the oil and water remain for months adhering tightly to the sand grains. There is no accumulation at the top of the tube and segrega-

tion is practically negligible. If, however, a small quantity of gas is introduced or generated in the tube, the oil and gas instantly begin to rise to the top of the fold, the gas rising above the oil and the oil floating on the water between sand grains. The separation is effected by a gas under pressure as low as four pounds to the square inch and some of the oil will move at least a foot per day.

Experiments have shown, however, that oil will move up a very low angle when gas is present under a few pounds of pressure. It will readily move up dips of one half degree and probably up dips considerably less when the pressure is high.

Experiments under various conditions with bent tubes appear to throw some little light on the manner in which oil accumulations are effected and gives indication of a probable cause of some of the tight, impervious spots in oil-bearing sands.

THE OIL AND GAS BEARING HORIZONS OF THE ORDOVICIAN IN OHIO

By L. S. Panyity

Abstract

This paper reviews the development of the Ordovician oil production in Ohio and the difficulties attending the first application of geology. Conditions in the Trenton are discussed and the discovery of a new oil zone about 600 feet below the top of the Trenton, representing probably the St. Peter sandstone, is described.

RECENT PUBLICATIONS

PETROLEUM AND NATURAL GAS IN INDIANA

By Dr. W. N. Logan

State Geologist, Indiana, State Department of Conservation, Publication No. 8, 1920, pp. 279, plates 27, maps 36.

Chapter I, entitled Introduction, has a general comment on the importance of this topic to Indiana, and the need of protecting the people from dishonest promotion and incapable geologists. It also contains acknowledgments and a short bibliography.

Chapter II is devoted to a brief resume of the properties and origin of petroleum. There are tables showing by counties the wells drilled, those dry, and those abandoned since 1906; also a table of production and annual values since 1889 and through 1917.

Chapter III is devoted to natural gas, and discusses its character, origin, and the method of computing gas depletion according to the Manual of the Oil and Gas Industry, published by the Treasury Department. There is a table showing the production by years in Indiana since 1886, and some pressure readings by counties between 1910 and 1914.

Chapter IV is devoted to the mode of accumulation, and the relation of structure to accumulation of oil and gas. Various types of geologic structure are sketched. Those found in Indiana include the anticline, monocline, terrace, fault, and lens.

Chapter V deals with prospecting for oil and gas. It calls attention to the need of geological study in a new field, outlines the preliminary work, and includes a brief description of drilling outfits and materials, shooting, plugging, pumping, transportation, and storage.

Chapter VI contains a general outline of the geological conditions in Indiana. Here the rocks range in age from Cambrian to Recent. Average thicknesses with places of outcrop by counties are noted. Four major structural features are briefly described. (1, Cincinnati geanticline; 2, northern basin; 3, western basin; and 4, Mt. Carmel fault).

In the foregoing chapters Doctor Logan has introduced the subject of petroleum in such a manner that the average reader who may not be versed in geology can appreciate, in a general way at least, the conditions which prevail in Indiana. This involves some introductory statements which obviously are elementary, but which are necessary in a publication of this kind. The reasons for such an extensive quotation from the Treasury Manual regarding gas depletion (pages 21 to 25) are not clear unless it is because our studies of natural gas decline and reserve are so fragmentary and unsatisfactory.

The diagrams on pages 26 to 34 illustrate the more important types of oil and gas occurrence in Indiana, and emphasize the importance of care-

fully recorded well logs, and their correct interpretation. Figures 4, 5, and 11 are not known to apply to any Indiana fields. The geologic map in the front of the volume, the oil and gas area map opposite page 48, and the structure map on page 49 give the dominant features of Indiana geology which are generalized in chapter VI. This is followed by detailed descriptions of each county with structure maps on a larger scale where such are available.

These structure maps of portions of counties which accompany many of the county descriptions are valuable additions to the text. Five of these maps do not show any figures on the contour interval, however, and the reader is left to infer whether it is 10 feet, as on the other maps, or some different amount.

Summarizing the county descriptions, one finds that an oil or oil and gas production has been obtained in 26 counties, although the folded map opposite page 48 shows oil areas in 32 counties. The text material shows oil production in the following counties: Adams, Allen, Blackford, Cass, Davies, Delaware, Dubois, Gibson, Grant, Greene, Hamilton, Harrison, Huntington, Jasper, Jay, LaPorte, Madison, Marion, Martin, Miami, Pike, Perry, Porter, Randolph, Sullivan, Vigo, and Wells. With the exception of Allen, Hamilton, Harrison, and Perry counties, the map opposite page 48 shows production in the above group, and in addition some in Lake, Newton, Fulton, Wabash, Indianapolis, Shelby, Monroe, Knox, and Spencer counties.

Gas production with little or no oil has been recorded in 14 other counties, and is mapped as developed in 18 counties. The text reports gas production in Brown, Clark, Clinton Decatur, DeKalb, Fayette, Franklin, Hancock, Henry, Howard, Jefferson, Jennings, Lawrence and Rush counties. With the exception of Clark and Clinton counties the map opposite page 48 shows production in the above group, and also in Tipton, Wayne, Bartholomew, Ripley, Washington, and Knox counties. Thus it is seen that between 40 and 50 counties out of the total of 92 counties in the state have yielded gas or oil, or both, in paying quantity, and many of the remaining counties may prove to have commercial production.

The distribution of these productive areas as now developed, bears a marked relationship to the Cincinnati geanticline. This distribution offers valuable suggestions for further exploratory work. It seems very probable that many of these small productive areas may be enlarged by detailed sub-surface studies, and it appears equally reasonable that important new areas may be discovered. In most of this work thorough cooperation between the driller and the geologist is to be desired because the drift mantle which covers much of Indiana renders ordinary suface study in geology inadequate for this problem.

The report is a real addition to the Indiana Geological Survey bulletins, and should be welcomed by those who are interested in developing the petroleum resources of the state.

JAS. H. HANCE.

INFLUENCE OF FAULTING IN THE ILLINOIS FIELDS

By H. A. Wheeler

Engineering and Mining Journal, January 1, 1921, Pages 22-24.

This article is intended to call the geologist's attention to the relationship of faulting to oil and gas accumulation, and illustrations are drawn from various Illinois localities. Mr. Wheeler is convinced that where faulting precedes accumulation its effects may be beneficial, but where it follows such accumulation leakage of the hydrocarbons may result.

After a discussion of various localities, some of which are productive, whereas some others have not proved profitable, he concludes that Illinois faults were developed subsequent to oil and gas accumulation, and because of numerous fractures in southwestern Illinois, probably related to the Ozark uplifts this part of the state will prove discouraging in future exploration work.

To the reviewer, some of Mr. Wheeler's conclusions seem unwarranted and premature and a number of localities besides the Waterloo area may prove well worth more detailed study. If some of our able geologists are not mistaken, faults, with at least minor displacements, are not uncommon in many productive areas outside of Illinois. Most of the commercial oil and gas accumulations are in sedimentary rocks, which have been more or less deformed.

Since oil migration is chiefly upward into younger beds its accumulation would probably accompany the deformation of the beds where it is found unless we assume that most oil migrates a considerable distance horizontally from the mother material, an hypothesis less acceptable now than formerly.

Jas. H. Hance.

REVIEW OF ILLINOIS FOR 1920

By L. A. Mylius

Engineering and Mining Journal, January 22, 1921, Page 177.

In 1920 Illinois produced approximately 10,750,000 barrels of petroleum, about 12 per cent less than its 1919 production. The average value per barrel was $3.66 making a total for the year of $14,300,000. Gasoline from natural gas yielded a total income of about $1,300,000.

Approximately 381 holes were drilled, 110 of which were dry. Of these 381 completions, 350 were in Clark, Crawford, Lawrence, and Cumberland counties, 16 were in eastern Illinois north of Clark county, and 15 were scattered over the remainder of the state. The Trenton horizon has received some additional testing between Crawford county and the northern part of Coles county, and has added somewhat to the state's production. Shallow Pennsylvanian production has been augmented by new wells in Edgar and Macoupin counties. The Waterloo area in southwestern Illinois has proved productive also.

OIL SHALES OF INDIANA

By John R. Reeves

Engineering and Mining Journal, November 13, 1920, pages 954-55.

The New Albany shale covers some 500 square miles in Floyd, Clark, Scott, Jefferson, Jennings, and Jackson counties. The outcrops are found in a strip 10 miles wide and extending about 50 miles north from Ohio river at St. Albany, the thicker outcrops of over 100 feet being found along the western border.

Samples were taken carefully at many places in this area, and subjected to laboratory distillation, both dry and with steam. The results of these laboratory tests are per ton of shale, and are summarized as follows:

Oil Content	9.5 to 20 gallons
Gas	570 to 1836 cubic feet
Ammonium Sulphate	6 to 35.5 pounds
Fixed carbon	4 to 8.5 per cent
Volatile hydro-carbons	9.5 to 22.81 per cent
Ash	70.29 to 86.5 per cent

Some potash is also reported as obtainable.

The character of the shale is said to favor cheap quarry and steam shovel methods, and Mr. Reeves feels that the deposit is one which warrants serious consideration as a source of shale oil with valuable by-products.

Jas. H. Hance.

WESTERN ILLINOIS NOTES

Engineering and Mining Journal, October 23, 1920, Page 826.

The Irvington structure in Washington county is being tested by the Petro Oil ad Gas Company. Oil seepages in nearby coal shafts and proximity to the Sandoval pool have encouraged further drilling in this area.

Subsequent findings, which suggest a fault beteen this area and the Sandoval pool, have proved somewhat disappointing to the parties financing this work.

Jas. H. Hance.

AT HOME AND ABROAD

Current Notes and Personal Items of the Profession

It is contemplated to include in this new division of the Bulletin current notes regarding the profession, the whereabouts and doings of petroleum geologists and personal items which will be of interest to the members of the Association. Since news of this sort finds no other channel by which it may reach very many of those most interested in it, since it is the feeling of the executive committee and of many others who have expressed opinions concerning it that the publication of the Association should afford more than a record of the scientific papers presented at the annual meeting and should serve to as large a degree as possible as a medium for the interchange of information important to the profession, and since there is prospect of publication of the Bulletin from time to time through the year as material is in hand, it is hoped that the inclusion of these items may be found worth hile. Many of the American petroleum geologists are being called in increasing numbers to areas abroad. As the interests of the Association become more widely distributed and as the membership increases there is greater occasion for these records. Each member of the Association can assist in making these columns of increasing interest and should make it his business to do so. Items may be sent to chairmen of regional districts or direct to the Editor.

DR. JOHN K. KNOX, who has been associated for the past year with the firm of consulting geologists, Harrison & Eaton, left early in December for geological work in India for the White Oil Corporation of London. His address is care of R. C. Blackwood, 8 Race Course Road, Lahore, India.

DR. DOUGLAS R. SEMMES, formerly Professor of Geology at the University of Alabama, is now in Tampico, Mexico, where he is employed as Assistant Chief Geologist for El Aguila, the leading British Corporation in the Mexican petroleum industry.

MR. GEORGE A. ELLEDGE, formerly geologist with the Humble Oil & Refining Company, is now Chief Geologist for La Atlantica, one of the larger petroleum corporations with headquarters at Tampico, Mexico.

MR. THOMAS A. HARRISON has resigned his position as Chief Geologist for the Mid-West Refining Company and will devote his time exclusively to private work.

DR. WINTHROP P. HAYNES, Associate Professor of Geology at the University of Kansas, has been in northern Mexico for the past six months where he is engaged in geological exploration for one of the large petroleum corporations.

MR. CLARENCE OSBORNE has been made Chief Geologist for the Mid-

West Refining Company. Mr. Osborne was at one time Consulting Geologist for the California Highway Commission, but has been on the geological staff of the Mid-West Refining Company for several years past.

MR. ROBERT W. PACK, formerly Chief Geologist of the Sun Company, has been made General Superintendent for that Company's Gulf Coast Division, with headquarters at Beaumont, Texas.

MR. S. G. GARRETT, formerly in charge of the subsurface geology for the Humble Oil & Refining Company has become Chief Geologist for the Fensland Oil Corporation with headquarters at Fort Worth, Texas. Mr. Garrett will be closely in touch with leasing and production, in connection with his geologic work.

MR. E. G. WOODRUFF, formerly Chief Geologist for the Oklahoma Producing and Refining Corporation, has assumed charge of the work of the International Oil & Transport Company, with headquarters at Tulsa, Oklahoma.

MR. J. M. LOVEJOY, formerly Geologist for The Texas Company, is now in charge of the Oklahoma division for the Amerada Petroleum Corporation.

MR. D. W. WILLIAMS, formerly Chief Geologist for the York State Oil Company, with headquarters at Caney, Kansas, has become Chief of the Oil and Gas Division of the State Geological Survey of Kansas, at Lawrence, Kansas.

MR. FREDERICK B. PLUMMER, with the Roxana Petroleum Corporation, has been transferred to the home offices of the Dutch Shell Company at The Hague, Holland.

DR. FREDERICK LAHEE, has succeeded Mr. R. W. Pack as Chief Geologist for the Sun Company, with headquarters at Dallas, Texas.

MR. FRANK BAKER has assumed charge of the geological work of The Texas Company, following the resignation of Mr. C. R. Eckes.

MR. PAUL APPLIN, Geologist for the Mid-West Refining Company has spent a portion of the winter at his home in New Hampshire.

MR. E. W. AMES has resigned his position in charge of the geologic work of the Pierce Oil Corporation in Texas, to engage in private work in north central Texas. Mr. Ames' headquarters are at Breckenridge.

MR. JOHN R. SUMAN, at one time Geologist for the Southern Pacific and later Superintendent of Production for the Roxana Petroleum Corporation in north Texas, has assumed charge of the Production Department of the Rio Bravo Oil Company, a subsidiary of the Southern Pacific, with headquarters at Houston, Texas.

MR. R. P. MCLAUGHLIN has resigned from the office of Oil and Gas Supervisor of the State of California. Mr. McLaughlin was the first

incumbent of this position and is largely responsible for the laws concerning the supervision of oil and gas development in California. He has been identified with this work for the past six years.

MR. CHARLES R. ECKES, formerly Chief Geologist for The Texas Company, has taken charge of a large concession in Venezuela, owned by British capital.

MR. BEN BELT, formerly in charge of the geologic work of the Gulf Production Company, under L. P. Garrett, has spent most of the past year in Mexico, where he has directed the work of the Mexican-Gulf Oil Corporation.

MR. FRANK DALBURG, formerly Geologist with the Humble Oil & Refining Company, is now in charge of the West India Oil Company's concessions in Venezuela. His headquarters are at Caracas.

MR. R. E. CULLOM has been appointed Oil and Gas Supervisor for the State of California, to succeed R. P. McLaughlin, resigned.

MR. H. E. MINOR, previously in charge of Sinclair's geologic work on the Gulf Coast, has resigned to take charge of similar work for the Gulf Production Company.

MR. K. C. HEALD, of the United States Geological Survey, spent a large part of last year in South America, where he was engaged in petroleum geology.

MR. O. B. HOPKINS formerly with the United States Geological Survey, is now in charge of the geologic work of the International Petroleum Company, in South America. Mr. Hopkins' headquarters are at 56 Church Street, Toronto, Canada.

MR. JON UDDEN, Geologist for the Sinclair Oil Corporation, has moved his headquarters from Fort Worth, to Tulsa.

MR. J. J. VICTOR has gained considerable fame as the discoverer of the ElDorado, Arkansas, oil and gas field. Victor's accomplishment in this instance is clean-cut without question. When he made his location for Eugene Constantine, near the town of ElDorado, he was about as far from existing production as he could conveniently get, and he certainly had nothing else than geology to guide him in choosing the site for his test.

MR. E. B. HOPKINS, New York City, Consulting Geologist, is at present in Venezuela on professional work.

DR. JAMES S. HANCE is now on the staff of the Illinois Geological Survey, Urbana, Illinois.

Among Petroleum Geologsts present at the annual meeting of the Geological Society of America at Chicago in December, were W. E. Pratt, W. E. Wrather, E. de Golyer, Sidney Powers, C. E. Decker, J. Elmer

Thomas, K. F. Mather, C. W. Washburne, J. A. Udden, Frank Buttram, W. H. Emmons, J. H. Gardner, L. C. Glenn, J. S. Hance, R. C. Moore, D. W. Ohern, I. C. White, E. H. Sellards, E. W. Shaw, Stuart St. Clair, V. O. Tansey, A. J. Williams, W. H. Twenhofel and Frank De Wolf. Papers were read by Powers, Udden, Emmons, Moore, Sellards, Johnson and Twenhofel. Doctor White last year President of the American Association of Petroleum Geologists, was retiring President of the Geological Society of America and presented as his presidential address a very interesting discussion of the development of the petroleum industry and the application of geological science in this field. The sessions of the newly organized Society of Economic Geologists contained a number of papers on phases of petroleum geology and were attended by many of the members of the American Association.

DR. A. D. BROKAW, of the firm Brokaw, Dixon, Donnelly, Garner and McKee, New York City, is at present beating the trackless jungles of Central America, according to report.

MR. FRANK A. HERALD, after petroleum valuation work in Roumania and Poland and work on a pipeline project from LeHavre to Paris, has returned to the New World and is now head of the Geological Department of the Companias Del Agwi, a subsidiary of the Atlantic Gulf Corporation, with headquarters at Tampico, Mexico.

MR. HENRY HINDS has taken the position of Chief Geologist for the Buckley Oil Company and is situated at Tampico, Mexico. Previously he had been doing work abroad for the Sinclair Consolidated Oil Company.

MR. GRADY KIRBY who was engaged in geological work for the Roxana Petroleum Corporation in Texas has more recently been engaged for Brokaw, Dixon, Donnelly, Garner and McKee in the vicinity of Maricaibo, Venezuela. His address is care Maricaibo Oil Company, Maricaibo, Venezuela.

MR. H. M. SCOTT is now with the Riverland Company of Tulsa, as Geologist.

MR. I. E. STEWART is located at Lewiston, Montana, where he is engaged in consulting work as a member of the firm of Stewart and Wright.